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CHAMBERS'S EDUCATIONAL COURSE.

INTRODUCTION TO THE SCIENCES

NEW EDITION

LONDON
W. & R. CHAMBERS 47 PATERNOSTER ROW
AND HIGH STREET EDINBURGH
1871.

Edinburgh:
Printed by W. and R. Chambers.

PREFACE.

The present volume, while calculated also for private and self-instruction, is chiefly designed to occupy that part of the attention of young persons at school, which has hitherto been devoted to the earliest of the usual series of *Collections*. Not less intelligible than the simplest of that class of school-books, it possesses the advantage of a definite and most important object, inasmuch as it presents a connected and systematic view of Nature. The sciences treated of are Astronomy—Natural Philosophy—Geology and Physical Geography—Meteorology—Electricity and Magnetism—Chemistry—Botany—Zoology—Human Physiology—and Mental Philosophy, upon each of which a series of *questions* is given at the end of the work. The amount of information on each is necessarily not great; but it has been the ambition of the writer that the information given should not be a superficial view of a few unconnected phenomena, but a chain of principles, calculated, in combination, to impress a distinct and comprehensive idea, and to make it possible that even those who leave school at the early age of ten, shall not go into the world without some knowledge of the parts of which it is composed, and the laws by which it is regulated. For the completion of a right elementary education, it is of course deemed necessary by the Editors, that each of the sciences here treated, besides several others, be studied separately, at least to the extent in which they are treated in the respective volumes of Chambers's Educational Course.

INTRODUCTION TO THE SCIENCES.

EXTENT OF THE MATERIAL WORLD.

1. In whatever place we first become aware that we are living beings, the scene which we survey is limited to a very small part of the whole system of Nature—that is, of what exists. If we look beyond the house in which we live, we probably see other houses, fields, hills, plains, or a part of the sea. If we look upward, a more extensive view is presented; we there behold the clear blue sky, where the sun shines by day, and the moon and stars by night. But even these large plains, and that wide sky, are only a part, and a very small part, of what exists. Far beyond the hills which bound our view, there are other plains and hills; and far beyond the stars which we see by night, there are other stars without number.

2. Every young person has some notion of the distance called a mile. If he were to walk a few miles from the place where he lives, he would come to other places quite strange to him; and if he were to walk many more miles, he would still come to new places. The parish in which he lives is only a few miles in extent; but this parish is but a part of a county, which is again part of a state or kingdom. The state is probably many hundreds of miles long, and some hundreds broad, and it contains so many people, that it is not easy for a child to understand their number. But, after all, a state is only a small part of the surface of the earth.*

* An effectual mode of impressing on a young person an idea of the situation of his home upon the globe, may be practised in schools where there are a black-board and some maps. On the black-board, a ground-plan of the school may be given; then a plan of the town, with the school reduced to its comparative size; next a plan of the county or district, with the town reduced: afterwards, the situation of the district may be pointed out in a map of the country, and finally, the situation of the country in a map of the globe. If any care be taken, at the various stages of this process, to give an idea of the relative

3. It seems strange that it is not a level surface which we stand upon, but a globe, shaped somewhat like an orange. The firm earth beneath our feet is nothing else than a large ball—so large, that the greatest extent of surface which the eye can see at one time appears quite flat. To assure ourselves that the earth is round, we may, on a clear day, look out from some high ground upon the sea, when we shall see the tops of

approaching vessels first appear, and gradually the lower parts. The earth is about eight thousand miles in diameter or thickness, so that its circumference or girth is twenty-five thousand. Nearly three-fourths of its surface is covered with water, forming seas and oceans. The remainder is very irregular, presenting hills and ranges of mountains, with valleys, slopes, and plains. The land is covered with a great variety of herbs and trees, and inhabited by many kinds of animals. Mankind, either in a civilised or savage condition, occupy the surface, and, as they differ from each other in language and manners, they have arranged themselves into nations, states, and kingdoms.

4. Although the earth may seem very large, it is, after all, only the third of a set or system of globes, called planets, which move at different distances in space, round the sun, and all of which are supposed to be occupied by living beings, and the things necessary for their sustenance. The moon is a small globe, which moves in like manner round the earth; and some of the other planets have moons moving round them. The sun, which gives light and heat to the planets, is a body of vast size—one million three hundred thousand times larger than the earth. The earth is distant from it ninety-five millions of miles, and the last or outermost of the planets is distant from it two thousand eight hundred millions of miles. If there were a road from the earth to the sun, and a man were to ride along that road at the rate of a mile in the minute,

extent of each place within the other, the pupil will at last arrive at a *comparatively* correct notion not only of the situation of his home, but of the relation borne by the scene within his view to the whole extent of the globe.

which was the speed of the swiftest horse ever known, he would require a hundred and eighty years, or twice the longest lifetime, to perform the journey. Great as is the space occupied by the sun and planets, it is but a small portion of the universe. Every little star which is seen twinkling in the sky is a sun like ours, supposed to be surrounded, too, with a similar system of planets, which, like our earth, are supposed to be the residences of animated creatures. Though the stars seem near to each other, they are, in reality, millions of millions of miles distant. Nor do we see all. When we look through a telescope, which is an instrument for bringing within our sight objects too distant to be seen with the naked eye, we discover many more stars; and always the greater power we give to the telescope, we bring more into view. The number of the stars is indeed beyond all calculation. 3.

5. What is here stated has been made quite certain by the inquiries of learned men; but it does not yet, apparently, comprehend the whole of nature. There is reason for supposing that the stars which we see with the naked eye and with ordinary telescopes, form but one cluster of worlds moving in space. Far beyond the bounds of this vast cluster, astronomers had long perceived cloudy specks on the dark ground of the sky; and, by the use of telescopes of extraordinary power, many of these little clouds have now been shewn to consist of separate points of light, and to be, in fact, groups of stars, but made to appear small and crowded together by being so far off. Indeed, it is impossible to conceive a limit either to space, or to the power of the Creator.

MATERIAL—composed of matter, or that which is perceived by the senses; in opposition to *spiritual*, that which is not perceived by the senses.

NATURE—literally, that which is born, from *natus* (Latin), born; a comprehensive term for the Deity's works, and the laws by which He rules them. The object of science is to discover the character of those works and those laws.

PLANET—from *planao* (Greek), I wander; the planets appearing to shift their places in the sky, while the stars always maintain one place relatively to each other. In distinction from the planets, the latter are called the *Fixed Stars*.

SYSTEM—from the Greek *systema*, a composition; a combination of many things acting together.

TELESCOPE—from the Greek *tele*, far off, and *scopeo*, I look at. This instrument is always in the form of a tube; but one kind is furnished only with lenses, through which the heavenly objects are seen magnified, while of the other kind the principal part is a concave mirror of polished metal, in which a magnified image of these objects is seen reflected.

THE STARS.

6. As already mentioned, the stars are supposed to be suns, or centres of light and heat, with planets revolving around them. The naked eye can only discern about four thousand, which have been classed in six *magnitudes*, with a regard to their various degrees of light; the largest stars being of the first magnitude, the next largest of the second magnitude, and so on. But when telescopes are employed, vast numbers, which are invisible to the naked eye, are brought into sight. Of the first magnitude, there are about twenty stars; of the second, about sixty. Many of these have particular names, which were given to them long ago by astronomers. Of the third magnitude, there are about two hundred. The visible stars are scattered irregularly over the heavens; and in some instances, a few, taken in combination, form figures which may be likened to familiar objects upon our earth. For instance, a group in the northern part of the sky resembles an animal with its tail thrown far out behind its body; while another group, which in winter we see in the south, suggests the figure of a man with a belt, and a sword by his side.

7. It has been found convenient by astronomers to suppose the whole of the visible stars as forming figures, in order that the situation of any particular star may be readily described by one person to another. These figures are called *constellations*, a word signifying a number of stars taken together. The cluster resembling an animal with a projecting tail is called the *Great Bear;* the cluster resembling a man with a belt, and a sword by his side, is called *Orion*, from a fabulous hero of antiquity. The whole expanse of the sky has thus been mapped out into forms of men, women, beasts, fishes, and other objects, all of which are figured upon our celestial globes.

8. The largest star in the sky is one in the south, called *Sirius*, or the *Dog-star*. It is not, however, the nearest. Astronomers were for a long time baffled in trying to measure the distance of the stars; they could only say that none of them were within a certain number of millions of miles. At last they have succeeded in ascertaining the actual distances of several. The nearest star yet known is one in the southern heavens; its distance is found to be twenty millions of millions of miles. Although light travels at the rate of about 200,000 miles in a second, the light of this star must take more than three years to come to us. Sirius is nearly four times as far off as the nearest star; so that the light that strikes our eyes when

we look at that star must have left it twelve years ago. But the distance of Sirius, or even of the furthest-off star of this inner cluster to which our sun belongs, is as nothing, compared with the distance of any of those outer clusters, of which we were speaking. Between the furthest-off stars of our cluster and the nearest stars of any other cluster, there lie empty gaps that cannot be fathomed even by the imagination. When astronomers try to conjecture how long time the light by which we now see one of those dim specks may have been travelling, they reckon the years by millions!

9. The stars are more numerous in some parts of the heavens than in others. This is owing to the form of the cluster of stars to which our sun belongs. It is shaped like a disc or coin, and our sun is not far from its centre. We, of course, see more stars when looking towards the extremities of the cluster than when looking towards its sides; just as, if we were in the midst of a strip of plantation, we should see more trees in the direction of its length than looking cross-ways. The denseness of the stars towards the extremities of the cluster, and the distance at which they are placed from us, cause them to melt into a thin light, which we see in the form of a ring passing across the heavens, and which the ancients called the *Galaxy* or *Milky-Way*. A powerful telescope directed towards any part of that galaxy, shews the stars of which it is composed, and how numerous they are.

10. Some of the more conspicuous stars, when inspected through a telescope, are found to consist of two, which revolve round each other in a greater or less space of time, and are of various colours—some blue, others reddish, and others green. These are called Binary Systems—binary signifying the condition of *two in connection*. Other stars, again, make periodical changes in their size and brilliancy, apparently in consequence of an alternate advancing and retiring, in and out of our sight. Some of these grow less and bigger in the space of two or three days; others in all spaces of time within five hundred years.

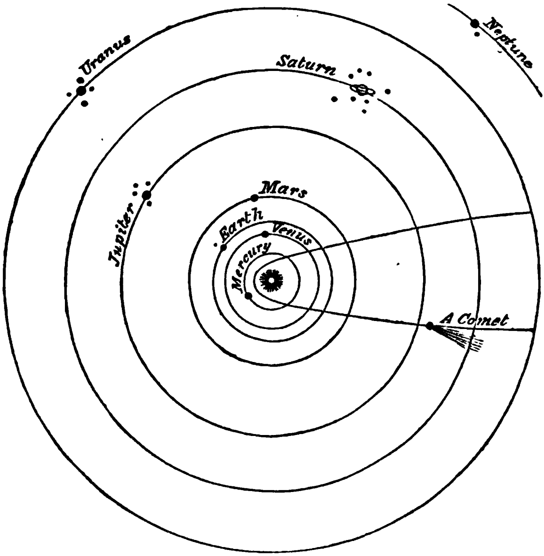
GALAXY—from the Greek *gala*, milk; the appearance of this object being somewhat like that of a stream of milk.

SOLAR SYSTEM.

11. The sun, and the planets which circle around it, are called the Solar System—*solar* signifying what belongs to the sun. It is represented on the next page.

12. Here the sun is in the centre, while planets named Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus,

and Neptune, are seen to revolve at various distances around him. But beside these eight large planets, there are a great many small ones, called *planetoids*. They all revolve in the

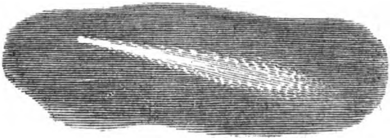


Solar System.

space between the orbits or paths of Mars and Jupiter, and are of very small size, so as to require a good telescope to see them. Fifty-six planetoids have already been discovered, and several new ones are every year added to the number. They have all got names, but the list is too long to remember. In reality, the circuits of the planets are slightly oval, the sun being placed nearer to one end than the other. They are all nearly, but not quite, in the same plane.

13. Comets are another class of bodies connected with the solar system. Their usual appearance to the naked eye is that of a star with a long streaming tail. When inspected by telescopes, they are generally found to be composed of a light matter, through which the stars can be seen, while the tail is still more light and vapoury. Some comets have been seen with more tails than one: a comet, in the year 1744, had six.

These luminaries differ from the planets in their motions: they travel in all directions far into space, and on their return pass very near to the sun's body. Many hundreds of comets have been ascertained to exist, and the periods at which some



Comet.

approach the sun have been calculated. But new ones are constantly coming under notice. One very celebrated one, called Halley's Comet, on account of the astronomer who first calculated its revolutions, approaches the sun once in seventy-six years: its last appearance was in the year 1835. Another, called, for the same reason, Encke's Comet, performs its revolution in less than four years. Donati's Comet, seen in 1858, is estimated to have a period of two thousand years. The uses or purposes of comets are not known.

14. Mercury, Venus, and Mars are about the same size with, or somewhat less than, the Earth. An attendant planet or satellite, which we call the Moon, revolves round the Earth, at the distance of two hundred and forty thousand miles. Jupiter is the largest of all the planets. Its thickness or diameter is eleven and a half times greater than that of the earth, and it is attended by four satellites. Saturn is of a diameter nine and a half times greater than that of the Earth; it is surrounded by two, if not three, thin plates or rings at different distances, and has eight satellites. Uranus has a diameter less than half that of Saturn, and has six satellites. Neptune is about the same size as Uranus, and has at least one satellite.

15. The distances of the planets from the sun are as follows: Mercury, 37; Venus, 69; the Earth, 95; Mars, 145; Jupiter, 494; Saturn, 906; and Uranus, 1800, millions of miles. Their periods of revolution are respectively, Mercury, 88 days; Venus, 225 days; the Earth, 365¼ days; Mars, 687 days; Jupiter, nearly 12 years; Saturn, 29½ years; and Uranus, nearly 84 years.

16. The sun, when inspected through a telescope, is found to be a body with a luminous exterior or atmosphere, in which small openings occasionally take place, so as to disclose a dark interior. These occasional openings are usually called spots

upon the sun, and their existence has been the means of detecting a movement of the luminary upon an axis, corresponding with the direction in which the planets move. The sun requires about twenty-five days to perform this revolution. The planets, besides their motion round the sun, perform, like that luminary, revolutions on their axes, which, in their case, produce the phenomena of day and night. These revolutions are all in a particular direction, which can only be described conveniently by saying that it is from west to east.

PLANETOID (Greek)—a planet-like body, or a small planet.

COMET—from the Latin *coma*, hair; comets are so named from the streaming appearance of their tails.

LUMINARY—from the Latin *lumen*, a light; a general term for the heavenly bodies, as they all send forth light.

SATELLITE—from the Latin *satelles*, an attendant.

ATMOSPHERE—from the Greek *atmos*, vapour, and *sphaira*, a sphere. Atmosphere may therefore be defined as a sphere of vapour enveloping another sphere of more solid materials.

AXIS (Latin)—the pin on which a wheel revolves. In astronomy, the axis is an imaginary line through the body of a sphere, on which that sphere is supposed to turn.

PHENOMENON, plural PHENOMENA (Greek)—acts and appearances in nature.

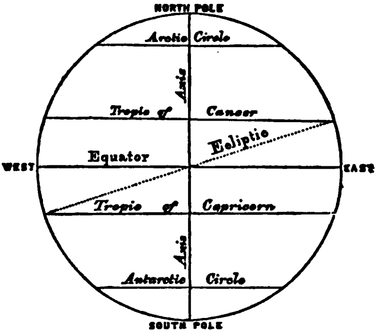
THE EARTH AS A PLANET.

17. The earth, as already mentioned, is the third of the planets, reckoning them by their distances from the sun. It is a globe of 7912 miles in diameter, and is surrounded by an atmosphere of about forty-five miles in height, the purpose of which is to support animal and vegetable life. It is provided with one satellite or moon, which revolves around it in nearly twenty-eight days. Its own revolution round the sun is performed in 365 days, 5 hours, 56 minutes, and 57 seconds, which constitute the space of time called a year. Its revolution on its axis is performed in twenty-four hours, or one day.

18. For the sake of convenient description, the figure of the earth has been marked with various imaginary points and lines, which it is necessary to understand before we can well acquire any knowledge of either the heavens or the earth.

19. Let it first be understood that the direction from which the earth moves is called the *west;* that towards which it moves, the *east;* that the point which is on the right hand of one standing with his back to the east is called the *north;* that on the left hand, the *south.* Those who first inquired into these subjects, imagined the heavenly frame as moving in its daily revolution upon an axle, such as is actually used in

the construction of our artificial globes: the end or pivot of this axle towards the north they called the *North Pole;* that towards the south, the *South Pole.* The names of north and south poles were afterwards transferred from the heavens to the points on the earth opposite to them; and as the inquirers dwelt on a part of the earth nearer the north than the south pole, they supposed the former to be uppermost, though in reality such ideas as upper and under do not belong to astronomy. It is for this reason that, in globes and maps, the

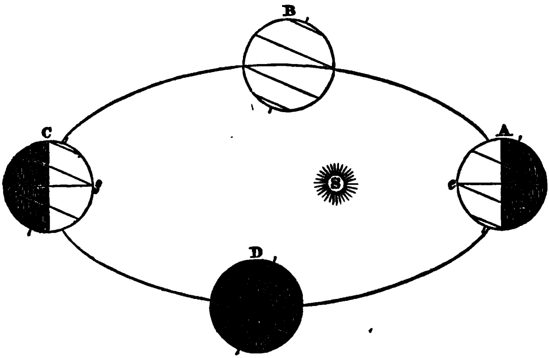


northern part is always placed uppermost, the east being towards the right, and the west towards the left hand, with the south at the bottom.

20. Exactly between the two poles, a line, termed the *Equator,* has been drawn all around the figure of the earth. This has been divided into 360 spaces, termed *degrees,* each of which contains about 69¼ English miles. Similar circles, called *Meridian Lines,* have been drawn in the contrary direction, so as to cross the equator at right angles. Ninety degrees intervene betwixt the equator and the pole in each direction. At the distance of 23½ degrees from the equator, to the north, a line parallel to the equator has been drawn, and is called the *Tropic of Cancer,* on account of the constellation in the corresponding part of the sky. At the same distance towards the south, a parallel line, called, for a similar reason, the *Tropic of Capricorn,* has been drawn. The intervening space is called the tropical regions of the earth. At the same distance from the poles, parallel lines have been drawn, which bear the names of the *Arctic* and *Antarctic Circles.* Another line, encircling the earth, but touching at opposite

points in the tropics, and cutting the equator obliquely, is called the *Ecliptic.* Properly, the ecliptic is the path in the heavens along which the sun seems to travel in the course of a year; and what is called the ecliptic on a globe of the earth, is a line drawn on the earth's surface in the corresponding direction. The points where the ecliptic cuts the equator are called the *Equinoctial points,* and when the sun is in that part of his course, the day and night are of equal length. These equinoxes occur twice during the year.

21. These lines, artificial as they are, refer to natural circumstances. The earth does not move with its pole quite upright or perpendicular, but in an inclined or stooping posture, the departure from the perpendicular being as much as 23½ of the 90 degrees constituting the quarter of the circle. This oblique arrangement produces those beneficial and agreeable variations of heat and light which we term the *Seasons.* In the next engraving, the sun is represented as nearly in the centre of the oval orbit of the earth. The earth is seen at four different



points in its annual course. At B and D, where it is on the 21st of March and 21st of September, the heat and light of the sun hit it at the equator. When the earth is at A, the upper or north pole is in darkness, and the sun is not there seen for several weeks. When it is at C, the south part of the globe is in the same state. And when one pole is thus darkened, the opposite one has constant daylight for the same length of time. Every day at noon, the earth presents a different part of the ecliptic towards the sun; and his heat is there for the time

the most powerful. When the point presented towards the sun is at *e*, which it is on the 22d of December, it is midsummer to all the southern parts of the earth, and winter to all the north. As the exposed part advances towards the point *f*, the northern regions of the earth gradually enjoy more and more heat, till, on the 21st of June, it becomes their midsummer.

22. The heat of the sun chiefly acts in a direct line, and upon objects which are directly opposed to it. Hence it is chiefly felt within that part of the earth traversed by the ecliptic—in other words, within the tropical regions—where the surface is presented to him at a right angle, or nearly so. The further a place is to the north or south of those regions, his rays strike the surface more obliquely or slopingly, and the climate becomes cooler—till, in the extreme north or south, water is scarcely ever found except in the shape of ice or snow. These variations of the sun's heat are a most important part of the system of nature; for the vegetable productions of the earth, upon which men and animals depend for their subsistence, require, for being ripened, exactly those proportions of cold and warm weather which the sun provides for them, and would cease to exist if these proportions were materially deranged.

23. As the earth turns on its axis once in twenty-four hours, each place on its surface at the equator moves at the rate of 1040 miles in an hour, or above seventeen miles in a minute. In places at a distance from the equator towards the north or south, the motion is less rapid, as there is there a smaller circumference to wheel round in the same time. Yet at any part in the British islands, we may be said to be carried daily through space at the rate of six hundred miles an hour. This turning of the earth on its axis is what causes *day* and *night* to follow each other. In the last figure, one side or half of the earth appears lighted up by the sun, and the other half is in darkness. The globe is constantly in this state; but, in consequence of the turning, every part has its share of light and darkness in succession. In turning from the west to the east, some part is constantly coming within sight of the sun, and at that place the sun appears to be rising. The place moves onward, so as to come more directly under the influence of the sun, until, at noon, it is directly opposite. In proceeding, it gradually leaves the sun behind, until he seems to sink in the west, and night follows. While he seems, however, to be setting at one place, he is rising to another on the opposite side of the globe, and producing every intermediate hour and minute of the day and night at some intermediate place.

24. For every *degree* of difference in the situation of places along a line from west to east, there is a difference of four minutes in the time of those places. Thus, when it is twelve o'clock at Liverpool, it is twelve or fourteen minutes before twelve at Dublin, for there are above three degrees of difference in the situations of those places. So, also, when it is half-past four o'clock at Glasgow, it is twenty-five minutes to five at Edinburgh, the one city being more than a degree to the west of the other. So, also, when it is mid-day in Britain, and all people are up and busy, it is near midnight in New Zealand, which is on the opposite side of the globe, and most people are there asleep.

25. Within the arctic and antarctic circles there is a certain time in summer during which the sun never sets, but circles round and round near the horizon; and a certain time in winter during which he never rises. At the poles, these alternate periods amount to the full half of the year.

POLE (Greek)—a turning point or pivot; the ends of the diameter or axis on which a globe turns round.

EQUATOR (Latin)—that which makes equal. This line divides the globe into two equal parts.

MERIDIAN—from the Latin *meridies* (instead of *medidies*, that is, *medius dies*), mid-day. To all the places along one of the meridian lines, the sun is at his greatest height at one point of time.

TROPIC—from the Greek *trepo*, I turn; the place at which the sun appears to turn back.

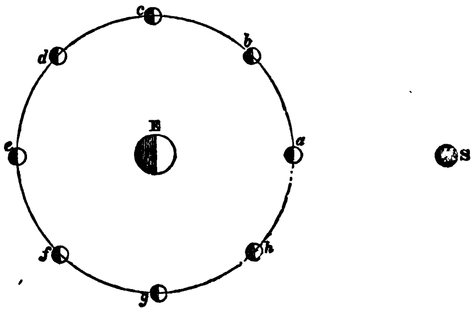
ARCTIC—from the Greek *Arctos*, the constellation of the Little Bear, in the tail of which is the pole-star, or star nearest to the north pole. *Antarctic*, from *anti*, against or opposite, *Arctos*, the Little Bear.

ECLIPTIC—so called from the moon's eclipses taking place when she is in a line with this path of the sun.

THE MOON—ECLIPSES.

26. The moon is a globe of about 2160 miles diameter, which revolves round the earth in twenty-seven days, seven hours, forty-three minutes, and eleven seconds. It has a motion on its own axis performed in the same space of time, and it also goes along with the earth in its circuit round the sun. The moon is not luminous in itself, but only reflects or throws back a little of the light of the sun, which thus becomes what we call moonlight. The changes in the appearance of the moon, from being a thin luminous curve, to a complete circle, are produced in the course of its revolution round the earth. When the moon is at the point furthest from the sun, we, being between the two, see the whole of the lighted side. As the moon advances to a point between us and the sun, the

lighted side gradually withdraws from our view, until it is wholly turned away. In the next engraving, the earth, E, presents a luminous face towards the sun, S, while the moon is represented in various parts of her circuit around the earth. At *a*, the dark side is towards the earth; at *b*, a quarter of the luminous portion is seen; at *c*, a half; at *d*, three-quarters; and at *e*, the whole. The moon is then full. It wanes to three-quarters at *f*, to a half at *g*, to a quarter at *h*. and at *a* it



becomes entirely dark, and is said to *change*. These variations are called the Phases of the Moon.

27. If the orbit or path of the moon were always on the plane of the earth's orbit, the moon would, every fortnight, either be between the earth and the sun, or have the earth between itself and the sun. But its orbit rises so much above, and sinks so much below, the plane of the earth, that it rarely causes and experiences this interruption of light. When it intercepts light from us, it is said to eclipse the sun: when light is intercepted from it by the earth, the moon is said to be itself eclipsed.

28. The lighted surface of the moon, as seen through a telescope, appears full of high mountains, which form the bright parts. Most of the mountains are in the shape of an elevated ring with an enormous pit in the centre, like the crater of a volcano; but no trace of an active volcano is to be seen. There is no appearance of water or vapour on its surface; nor has it any atmosphere. This luminary not only affords us a partial light, but by its attraction causes the tides. It is also very generally believed that the changes of the moon cause changes in the weather; and that she exercises many other mysterious influences. But it is now proved that the

connection between the changes of the moon and those of the weather is entirely imaginary; and probably this is the case with many of the other influences attributed to her.

29. The stars, the solar system, and the circumstances connected with the earth as a planet, form the subjects of the science of ASTRONOMY.

PHASE—from the Greek *phasis*, the appearance exhibited by any body.

ORBIT—from the Latin *orbis*, a globe, and *itus*, a journey; the curve described by one globe in its revolution round another.

ECLIPSE—literally, a falling away or waning, from the Greek *leipo*, I quit.

ASTRONOMY—from the Greek *astron*, a star, and *nomos*, a law; the science which treats of the nature, distances, and motions of the heavenly bodies, and of the laws by which they are regulated in their courses.

MASSES OF MATTER—LAWS OF ATTRACTION AND MOTION.

30. The bodies or objects which make up the world, and of the existence of which we are informed by our senses, are composed of a variety of substances, which go under the general name of *Matter*. The earth which we inhabit, the air which we breathe, the distant planets and suns, are matter, though some are much more solid or dense than others. A stone, for instance, is denser than water; water, again, is denser than cork; and cork denser than air; yet all are alike matter. The earth is more solid than the planet Jupiter, which has been ascertained to be as light as water; but still both are alike material. It is not improbable that the whole space in which the heavenly bodies move is filled with some extremely rare kind of matter.

31. Matter, in all its forms, is subject to various fixed rules or laws, which have been established by the Creator for very important ends. By one of these, it is ordered that every particle or mass of matter possesses a power of *attracting* other particles or masses. The attractive powers of matter shew themselves differently under different circumstances; or, rather, there are different kinds of attraction. One is the attraction of *gravitation*, which is so called because it gives heaviness or weight to bodies. It acts between bodies or pieces of matter both when they are close together, and also when they are at sensible distances from each other. When two bodies are of the same size and density, so that they contain both the same quantity of matter, they attract or draw one another equally; but if one contains twice as much matter as the other, the larger

draws the smaller with twice the force with which the smaller draws the larger; and so for any other proportion.

32. The strength of the attraction of one body for another varies, according as the bodies are near or far from each other; and, in speaking of this, the distance between the two bodies is to be counted, not from any part of their surfaces, but from the middle point of the mass of each body, where its attractive influence may be supposed concentrated. The strength of attraction diminishes with an increase of the distance, according to the following law. Suppose that one ball is drawing another towards it with a certain force, and that the distance between their centres is one foot; if the distance is increased to two feet, the force of the attraction is reduced to a fourth of what it was; if the distance is made three feet, the attraction becomes a ninth; if four feet, a sixteenth; and so on—the diminution being always as the *squares* of the distances; that is, the distances multiplied by themselves. The distance from the centre of any round mass of matter to its surface is called its *semi-diameter;* that is, the half of its diameter or thickness. If then there are two such masses, a large and a small, and if we ascertain how many semi-diameters of the larger the smaller is distant from it, and multiply that number by itself; the result shews how many times the attraction at this distance is less than if the two were close together. The moon, for instance, is distant 240,000 miles from the earth, or as much as sixty semi-diameters of the earth; 60 multiplied by 60 gives 3600; consequently, the attraction exercised by the earth upon the moon is a 3600th part of what it would exercise upon the same mass at its own surface.

33. Weight is entirely a result of the laws of attraction. The attractive influence of the earth pulls down and holds bodies to it. Thus, the falling of a body to the earth is only an effect of attraction, and the weight of a body is only a pressure downwards, in obedience to the same law of gravitation. As gravitation acts upon all the particles or atoms of matter in a body, and not upon the mere surface or superficial bulk, those bodies in which matter is most dense, or have the greatest number of particles, are the heaviest. *All falling bodies tend in a direct line to the centre of the earth, which is the centre of the earth's attractive power;* and, therefore, whenever we let fall a body from our hand, it proceeds in a straight line down to the surface, where it is arrested. This is well exemplified by the act of dropping a ball from our hands as we stand upon a slope or mountain-side. The ball does not fall towards the centre of the mountain, but in the direction of the earth's centre. What we call *down* and *up* are merely relative

terms. That which is down to us, is up in respect to those who live on the opposite side of the globe; and that which is up to us, is down to them.

34. The mass of the earth is so great, compared with the separate bodies on its surface, that it overpowers, as it were, their attractions for one another, and makes it very difficult to discern that they have any. Yet by delicate contrivances this may be done. Thus, when a ball is dropped from the hand on the slope of a mountain, it seems to fall, as we have said, in the direction of the earth's centre; but, in reality, it falls slightly towards the mountain, although it would be impossible to discern the deviation. The attraction of the mountain, however, can be made apparent in another way; for if the ball is suspended by a line, it can be shewn by accurate instruments not to hang perpendicularly, but to incline towards the mountain. By an instrument called a torsion-balance, it is also possible to make the attraction of a large ball for a small one discernible.

35. Attraction, as already stated, is strongest when the bodies are near each other. As we proceed upwards from the earth, it becomes weaker. For this reason, it has not so much strength at the tops of high mountains as at the level of the sea. Weight, consequently, differs in different situations. A ball of iron, weighing a thousand pounds at the level of the sea, if weighed in a spring-balance on the top of a mountain four miles high, will be found to have lost two pounds of its weight, in consequence of the attractive power of the earth being diminished to that extent at that greater remoteness from the centre. The earth at its equator has a diameter exceeding that at its poles by twenty-six miles; consequently, the surface at the poles is thirteen miles nearer the centre than the surface at the equator, a proportion being observed in all intermediate places. Objects are therefore found to weigh more heavily in a spring-balance as we advance from the equator to the poles. From the same cause, objects fall more rapidly at the poles than at the equator. Pendulums, being similarly affected, swing more actively at the poles than at the equator. For this reason, pendulums for regulating the motion of clocks require to be adjusted in length according to the distance of the place where they are used from the equator; because the longer the rod of the pendulum is, it vibrates the slower. A pendulum in Edinburgh would require to be a little longer than one in London, in order to vibrate exactly 60 times in a minute.

36. Gravitation, as already mentioned, does not act on the mere surface of bodies, or according to their bulk, but is exerted in reference to all the particles or atoms individually

which compose the mass of a body. In the case of liquids, in which the atoms slightly cohere, the atoms have liberty to spread themselves over the earth, and to seek the lowest situation for repose. In the case of solids, a different operation is observable. In them the particles of matter stick so closely together, that they are not at liberty to obey the laws of gravitation individually, but rally, as it were, round a common centre, upon which the force of attraction may be considered to act for the general behoof. This common centre, or point, is scientifically called the *centre of gravity*. This point in bodies always seeks the lowest level, in the same manner that water seeks the lowest level.

37. The centre of gravity in round, square, or other regular-shaped bodies, of uniform density in all their parts, is the middle point of these bodies. When a body is shaped irregularly, or when there are two or more bodies connected, the centre of gravity is the point about which they will balance each other. The disposition which the centre of gravity in bodies has to seek the lowest level, is the cause of the tumbling or overturning of bodies. Unless the base be made sufficiently broad, so that the centre of gravity cannot overhang it, the body must fall over. Heavily and highly loaded coaches and carts frequently overturn from the raising of their centre of gravity too high, and from the base or wheels of the vehicle not being wide enough to support them, when any jar occurs. In the various natural structures displayed in the animal and vegetable kingdoms, the centre of gravity is always so situated as to produce a just balance and harmony of parts.

38. Another kind of attraction is that which acts only between atoms or particles of matter that are close together, or in contact. This sort of attraction does not take place between all kinds of substances and in all conditions, as the attraction of gravitation does. It is the attraction we are now speaking of that makes the particles or atoms of which bodies are made up, stick together or *cohere*, so as to form one mass, instead of being like a heap of sand. When the particles of a substance cohere stiffly, so as not to slide upon one another, it makes a *solid* body, such as a stone or iron; if they cohere in some degree, but yet slide upon one another freely, they form a *liquid* like water; and if there is no cohesion, but rather repulsion, among them, they form a gas, as air.

39. One effect of the attraction of cohesion among the particles of a liquid is, that when a small portion is detached, and left free to take any shape it chooses, it gathers itself up into the form of a globe, as is seen in a drop of water. The attraction of gravitation would also have the effect of drawing

together a number of separate movable particles or bodies into a round mass. In consequence of this law of nature, it is considered probable that the globes of space, including our own earth, were originally in a fluid state—that, in that state, they unavoidably assumed a spherical shape, and were then hardened into their present consistency.

40. This sticking of particle to particle is not confined to particles of the same substance; it takes place between different substances, as when particles of dust *adhere* to an upright pane of glass, or sealing-wax to paper. But the effects of adhesion are most striking between solids and liquids. If the hand or a piece of wood is dipped into water, a film of water adheres to the surface, so that no force can shake it off. It is this attraction of solids for liquids that causes water to rise above its level in a narrow tube, and to be sucked up by a sponge or other porous body.

41. Another of the laws of matter relates to its movements. *Rest and motion* are equally natural to matter, and both alike result from certain circumstances. Thus, for instance, if a cricket-ball be allowed to lie upon the ground, it naturally remains at rest. If it be put into motion, it is natural for it to continue in that motion, in a straight line, until stopped by some resisting force. In the case of a cricket-ball driven by a bat, the air, which is another, though rarer kind of matter, presents a certain amount of resisting force. It encounters another obstruction in the friction or rubbing of its body on the ground; this obstruction being the greater in proportion to the roughness or unevenness of the ground. When at length *as much force has been exerted in stopping it as was exerted in setting it in motion*, it comes to a pause. Being ourselves placed in circumstances where the forces just described are constantly operating, we cannot well conceive that it is equally natural for a piece of matter to remain in motion as to remain at rest, for, on account of those forces, we always see motion sooner or later brought to a stop. But when we conceive a mass of solid matter set in motion through a space entirely free of all resisting forces, we readily perceive how natural it is for it to continue in motion, seeing that, in such circumstances, an amount of obstruction equal to the impulse is not to be found.

42. When a body revolves on an axis, the outer parts of course acquire motion. The tendency of the motion of these parts is, in reality, to go on in a straight line. They are only kept within the circle of revolution, because they are fixed. If any piece of the revolving body were suddenly detached or let loose, it would be seen to fly off in a straight line, being forced or impelled to do so by the motive power or force already

exerted upon it. We may observe this law operating when we whirl a stone round in a sling. The stone is then felt to have an inclination to start away, and if we suddenly let slip the string, it does start away with great speed. For the same reason, when a mop is twirled, we see each of the threads flying straight out, and they only cease to do so when the twirling is stopped. The tendency thus produced is called *centrifugal* (that is, centre-flying) *force*, in distinction from the force that holds the body from going out of the circle, which is sometimes called *centripetal* (centre-seeking) *force*.

43. In consequence of centrifugal force, the planets, in wheeling round the sun, have a tendency to fly away into space; and they would fly away, if they were not retained in a particular path or orbit by the attractive power of the sun. Thrown outwards by one power, and drawn inwards by another, they have settled into paths where the two forces balance each other, so that they can neither go further from the sun, nor come nearer to him, than they do. In each case, the rate of a planet's speed, and its distance from the sun, are circumstances exactly suiting each other; and were there the least change in the one, the other would need to be changed, to preserve the economy of the planet. Were the distance of the earth from the sun, for instance, to be lessened, the earth would require to move quicker, in order to keep itself away from the sun. In fact, the earth is, at one time of the year, a little nearer the sun than at another time, and, when nearer, it does move more quickly, and thus maintains itself in its appointed course.

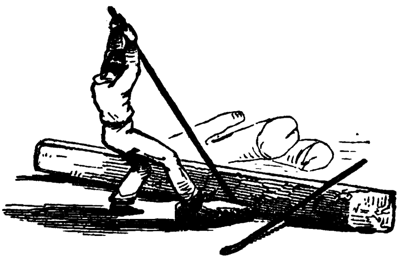
44. There are many other equally nice arrangements in the planetary system, which shew that it must have originated in accordance with fixed laws in nature, and that by these laws it is still sustained. It is supposed that the planets and the sun were originally one fluid, revolving mass; and that the planets were portions disengaged from the mass, which, by the law of attraction, necessarily assumed a globular shape, and by the laws of attraction and motion together, went on revolving in circular orbits. The laws by which these results are supposed to have been brought about appear very simple, for we see them operating in many familiar things on earth; but this apparent simplicity only serves the more expressively to shew the greatness of that Power which created both matter and its laws.

45. All objects connected with moving bodies possess a motion in common with these bodies. Thus, all things on the earth, including the atmosphere, have a motion in common with the earth; a person driving in a chaise has a motion in common with the chaise; a person in a moving vessel at sea has a motion in common with the vessel. The important thing

to observe about this common motion of a system of bodies is, that the individual bodies may move among themselves, and the result is the same as if no such common motion existed.

46. For example, when we leap straight upwards from the ground, the earth does not slip away from below us; we fall on the spot whence we arose. Sitting in the cabin of a moving vessel, if we let a small object drop from our hand to the floor, it falls on a point in the floor immediately below; the floor does not leave it behind. The reason is, that all the objects in and on the ship have a common motion onward derived from the ship, and anything let fall retains that motion during its descent. The onward motion remains in the disengaged bodies till they meet some new impression of force—something to stop them. If we attempt to leap from a moving body, such as a coach or a boat, we continue to possess the motion which we previously had, until we reach the earth, when we receive a shock by the destruction of the motion we possessed. If the motion of the vehicle be very quick at the time, it is scarcely possible, in making such a leap, to avoid being pitched forward, by the upper part of our bodies retaining the motion which our feet lose on resting on the ground. The motion we possess in common with the earth, and the perfect smoothness of the earth's motion, render us incapable of feeling our own motion, or of seeing the earth move along with us. Also, in driving in a coach, and looking at the roadside, we feel as if it were not the coach which was running, but the road, which seems to be moving past us.

47. By the application of a *motive* or *moving* force to solid objects, such as instruments, tools, or machines, very wonderful results are effected; as for example, when we see a man using



a bar or beam to raise a block of wood or stone, which he could not lift by his hands alone. The bar which is used for purposes of this nature is called a *lever*, from a French word signifying

to raise. The object which supports the lever where it presses against the ground is called the prop or *fulcrum*. By lengthening the lever betwixt the prop and the handle, we can increase the effect, or the power of lifting, to any extent; but the longer or more powerful we make the lever, the longer time is occupied in working it. In this manner, power is gained by a sacrifice of time, or a loss of quickness; and if we wish quickness, we must exert the greater force in proportion. By means of the lever and other implements or machines, man is enabled, at some sacrifice of time, to concentrate a long and comparatively weak effort of his strength into a short and powerful one; and thus to raise heavy weights which his unaided hands could not have stirred. Thus you see a man in a quarry turning the handle of a crane, and by this means lifting slowly a block of stone sufficient to load a cart. But for every inch that the block rises, the man has to move the handle over a great many inches.

48. By exercising his ingenuity, man can thus turn the strength of his muscles to far better account than if he used it directly and without skill. But in addition to this, the powers of his mind have enabled him to press the strength of horses and of oxen into his service; and what is still more, the inanimate powers of nature, such as the winds and streams, and, greatest of all, the power of steam. By yoking these, as it were, to machinery, he makes them do the hardest of the toil for him, so that he has only to superintend. At an inconsiderable expense, and with a small degree of trouble in attending to it, a machine may be made to do the work of ten, fifty, or perhaps as many as five hundred men; and the work so simply effected by inanimate mechanism, serves to cheapen and extend the comforts and luxuries of life to the great body of the people.

49. The operation of motive forces in connection with solid bodies forms the subject of the science of MECHANICS.

ATTRACTION—from the Latin *ad*, to, and *tractus*, drawn; the power by which one body draws another towards it.

GRAVITATION—from the Latin *gravis*, heavy; that peculiar kind of attraction which is exemplified in the tendency of bodies to fall towards the earth's centre; it is so called because it gives bodies their weight.

STRUCTURE OF THE EARTH—ROCKS AND MINERALS—SOIL.

50. It has been said that the general structure of the earth is solid. As far as man has yet observed, it seems to be composed of various kinds of rocks, earths, metals, and other substances—rocks being the principal material. All these substances constitute what is called the *Mineral Kingdom*.

51. Some rocks are always found in layers or beds, one above another, like slices of bread laid together, though they seldom lie quite flat or level. They are sometimes found, in this form, extending under great tracts of country. Other rocks are never seen in this form, but always in huge irregularly shaped masses. In the one case, the rocks are said to be *Stratified*—that is, disposed in strata or layers. In the other case, they are said to be *Unstratified.*

Unstratified. *Stratified.*

52. If an ignorant person were to inspect the crust of the earth in various places, by looking into quarries, and going down into mines, he would think the various kinds of rock very much confused: he would be apt to see no kind of order in them. It was generally thought that there was no order amongst them, till a period almost within the recollection of persons still living. But it is now ascertained that there is an order in the arrangement of rocks one above another.

53. First, as to Stratified Rocks: The various kinds are always found to observe a particular order as they lie above one another in the earth's crust. Thus, chalk-beds are never found below coal, nor coal below roofing-slate, though either chalk or coal may be immediately above roofing-slate. The whole of the Stratified Rocks may be said to form a series, as the letters of the alphabet do: there may be present only the first six, corresponding to *a, b, c, d, e, f,* or only six from different parts of the series, as *a, c, h, l, p, t*; but whatever are present, an order like that of the alphabet is invariably preserved.* Corresponding with the order is the *age* of rocks, the lowest being the oldest.

54. When we penetrate through the whole of the Stratified

* The following is another illustration at the command of the teacher: If we take a copy of a book in nine volumes, and range them correctly; then lay them down on their sides, one above another; the second will be found above the first, the third above the second, and so on. Suppose we take out the second and fifth volumes, still the third follows the first, and the sixth follows the fourth; the order of number is preserved.

Rocks at any particular place, we find the Unstratified forming, to appearance, the basis or floor on which all the others rest. At many places, these Unstratified Rocks rise into lofty mountains, so as to be on a higher level than the Stratified; and the Stratified Rocks are found resting upon, and sloping away from the sides of those mountains. Unstratified Rock is also found to have in some places burst up, in a molten state, through the Stratified, filling vertical openings and chinks in the latter rocks, and even to have spread over them like liquid lava.

55. The Unstratified Rocks are called *Igneous*, as having been produced under the agency of fire: in the special circumstances where they have been thrown up through openings and chinks, they are called *Volcanic*. The Stratified Rocks, again, have all been laid down as a sediment from water, and are therefore called *Aqueous* or *Sedimentary* rocks.

56. The Unstratified Rocks are of a hard, crystalline, and sparkling appearance. Four substances enter into their composition—mica, quartz, felspar, and hornblende; and, according as one or other of these substances is more largely infused in the composition, it passes by particular names, as, for example, Granite, Syenite, and Greenstone. *Granite* is generally a grayish shining stone, speckled with green or black, and of extreme hardness. Many ranges of mountains are composed of it. It is useful in building bridges, piers, and other structures designed to be lasting. Waterloo Bridge, in London, is of this stone. The statue of Memnon, and Pompey's Pillar, in Egypt, are composed of it. The city of Aberdeen, near which much granite is found, is entirely built of it.

57. The lowest group of Stratified Rocks partake generally of the same hard and crystalline character as the unstratified; indeed, one of these rocks, called *Gneiss*, is often so like granite, as to be hardly distinguishable from it. Others, as *Mica-slate*, *Talcose-slate*, *Clay-slate*, are of laminar structure; that is, capable of being cloven into thin slices. Clay-slate is thus fitted for being used in roofing houses and other purposes. The lowest Stratified Rocks are sometimes called PRIMARY, as having been first formed.

58. Operations which we see going on in nature enable us to form some idea of the way in which the Stratified Rocks have been produced. All stone is liable, when exposed to the air, to crumble away in powder. Water, in the shape of rain, rivers, or waves of the sea, wears it down still more quickly. Hence, there is no rocky mountain which is not constantly getting lower and less, and many coasts are in the course of being worn away by the sea. The particles thus disengaged

are generally carried into seas, and deposited at the bottom. In an early stage of the earth's existence, the Unstratified Rocks, originally formed by fire, appear to have been left in immense masses, interspersed throughout very large and profound seas. Matter worn off them would of course settle at the bottom of these seas, where, pressed by a vast weight of water above, and exposed to the heat which resides in the interior of the earth, they would readily be consolidated into beds of rock.

59. The wearing down of rocks is constantly going on at the present day, though perhaps to a less extent than in former ages. It is called the *Disintegrating Cause* or *Principle* (*disintegrate* meaning to make a thing not whole—to break it away in pieces). If this law had alone operated from the beginning of the world, all the dry land might have ere now been worn away into the sea, so that there would have been no ground for man or beast to live upon. But there is another law which balances or makes up for it: this is called the *Elevating Cause* or *Principle*. It seems to depend upon the working of fire underneath the crust of the earth. By it the rocks formed at the bottoms of seas are raised, either by sudden convulsions, or gradually, above the level of the sea, so that they become dry land. Islands have been thrown up in this manner in some seas within the memory of many persons living. There is a tract of country near the mouth of the river Indus, nearly sixty miles in length by sixteen in breadth, which was raised by an earthquake in the year 1819 ten feet above its former level. The shore of the Baltic sea, in the north of Europe, has perceptibly risen several feet during the last hundred years. This is the reason why sea-shells are often found in great quantities on ground far above the present level of the sea. When new land is thus thrown up, it immediately becomes liable to be worn away again by air and water, and carried back into the sea; so that nature may be said to keep up a constant system of change on the face of the globe.

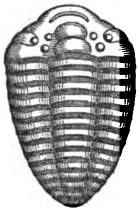
60. The matters disengaged from the Unstratified Rocks settled generally in different proportions of ingredients, probably from two causes. First, it may readily be supposed that, when loose matter is carried along by water, the heavier particles necessarily, by gravitation, fall to the bottom first, while the lighter particles are carried onwards to perhaps a considerably distant place. Such is the case when the matter is *mechanically suspended* in the water. In other instances, a more intimate or *chemical* union between the water and the matter contained in it seems to have taken place; and in such

cases, by the laws of chemistry, a separation of the ingredients of the matter would ensue. In gneiss, and mica and quartz rocks, we see a separation of materials by mechanical means. In clay-slate we see the product of chemical action. Clay, it must be observed, is a substance found in three of the ingredients of granite—mica, felspar, and hornblende. It must have been chemically separated from these, before being laid down in the strata which it has formed. It is generally to be remarked of the mechanically formed rocks, that they are looser and less crystalline in their texture than the Unstratified Rocks. The mica, felspar, and quartz of the original granite are in regular-shaped crystals, with sharp edges, while in the gneiss and mica-slate these crystals are broken into different shapes, and have a water-worn appearance.

61. In the series of Stratified Rocks, passing upwards, we come next to certain beds of *Sandy Slate*, nearly resembling some of the preceding strata. Next above are beds of a hard rock of grayish colour, composed of fragments of earlier rocks, and called *Greywacke*. Above this is a series of strata, many of which are of limestone, and which are called the *Silurian System*, because found at the surface in a part of England where the Silures lived in the time of the Romans. Still higher is another series, which, from the principal rock found in it, is called the *Old Red Sandstone System*. This system is chiefly composed of beds of *red* sandstone; but in the upper portion, the layers assume a *yellowish* cream-colour, and are very soft and fine in texture. Associated with this system are beds of *Conglomerate*, entirely composed of pebbles, from the size of a pea to that of a man's hand, these pebbles being firmly consolidated or cemented together. The beds of this rock, although from twenty to sixty feet in thickness, are simply the gravels of early seas. Puddingstone is another name for it, from its pebbles being crowded together like the fruit in a plum-pudding.

62. In the greywacke and the rocks above it, there are found remains of plants and animals which are presumed to have existed upon the earth at the time when those rocks were forming. Such parts of these plants and animals as have been preserved are all changed into the matter of the rock itself, but retain more or less exactly their original form, and even the minutest traces of their original structure, so that there can be no doubt about what they are. They are called *Fossils*, from their being dug out of the earth. From the whole range of these fossils, we can tell pretty clearly what kinds of plants and animals flourished on the earth during a long course of ages.

63. In the greywacke group of strata, fuci or sea-plants are found; likewise remains of corals and sea-mollusks, such as now exist in tropical seas, but not of the same species. In the Silurian series, the sea-mollusks and corals of the greywacke are continued, with the addition of crustaceans, or jointed shell-fish, and annelida or sea-worms. Among the mollusks was one curled up like a horn snuff-box, the creature living in the outer part; it is called the *Ammonite.* There was also a certain variety of the *Nautilus,* a creature which still exists in tropical seas. It is furnished with a small membrane, which it raises as a sail on the surface of the sea, so that it can skim along like a ship. One particular kind of the crustacea was a creature possessing a body of jointed plates, and a head with eyes calculated to look upwards from the bottom of the sea; it is called the *Trilobite.* Among the shell-fish of these early ages, there were some which lived upon others, as in the present day. In the Old Red Sandstone, besides all these, there are remains of fishes in great abundance, and of many different species, but considerably unlike any fish now existing, being covered with bony plates instead of scales.



Trilobite.

64. The next formation is the *Mountain Limestone,* consisting chiefly of thick beds of limestone resting upon dark-coloured shale (stone formed of mud), and layers of white sandstone. There are at some places six or eight beds of limestone, and at others only one of great thickness—namely, sixty or one hundred feet. This limestone is almost wholly composed of fragments of ancient corals and sea-shells; there were also many *crinoidea,* of which the *Lily Encrinite* may be taken as a specimen; it had a stalk and head like the flower from which it is named, the mouth and stomach being where the cup of the flower is situated, while the basis was firmly fixed to the bottom of the sea. The Mountain Limestone is so named from its being found in elevated positions, such as in the hills of Derbyshire; it is also called the *Carboniferous Limestone,* from its lying immediately under the coal strata which contain carbon or charcoal.

65. Above the Mountain Limestone there is a set or group of strata, comprising, amongst beds of ironstone, sandstone, and shale, those seams or beds of *Coal* which are so useful in many ways to man. Coal is composed of great quantities of trees and shrubs, which once grew green and beautiful on dry land, but were ultimately washed down into seas, and

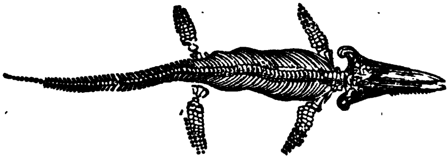
compressed under beds of mud and the weight of the ocean, till they became a stone-like mass. In many parts of the earth, but particularly in the neighbourhood of Newcastle, in the north of England, there are a great number of beds of coal, from a few inches to many feet thick, and having beds of sandstone and shale between them. From appearances of the original vegetables still seen in coal, it would seem that those vegetables were the productions of a warm climate: amongst them are ferns and horse-tails, of various species, but of the size of trees instead of lowly shrubs—also reeds and other aquatic plants, and some palms. It is inferred from these and other circumstances, that northern countries, now quite temperate, must have at one time been exposed to the same heat which now exists only near the equator.

66. Above the coal are found beds of sandstone, called, from its colour and situation, the *New Red Sandstone*. Sandstone is in general formed of grains of quartz and other early rocks, worn away, and deposited in the bottoms of seas, where it has been consolidated by pressure or otherwise. It is well adapted for building, as it is easily dressed, and is durable. The finest sandstone for building is found immediately below the Mountain Limestone. It is white in colour, and can be raised in blocks of any size. The famous quarries of Craigleith, near Edinburgh, and Cullelo in Fife, yield this kind of sandstone, and the beauty of the city of Edinburgh is in a great measure owing to it.

67. Next occurs a series of limestone-beds, called the *Magnesian Limestone*, from the quantity of magnesia contained in it. Amidst these beds are to be found others, chiefly consisting of marl and gypsum. Limestone is composed of the earth-lime, united with another substance called carbonic acid. Whence came the vast quantities of lime necessary to form the great and numerous beds of limestone in almost all parts of the earth, is a question which has not yet been satisfactorily answered: much of it was, perhaps, issued from the interior in springs, and some might be immediately furnished from the bodies of animals and the shells of fish, or from the great beds of calcareous matter formed by the coral insect. Marl is a loose earthy mixture of lime and clay, frequently containing a vast quantity of decomposed shells. When there is more lime than clay, it is said to be a *calcareous* marl; when more clay than lime, a *clay* marl; and when the shells are very abundant, a *shell* marl. Gypsum is a peculiar kind of limestone; it is composed of the earth of lime, united with sulphuric acid, and not with carbonic acid, as in the ordinary limestone. After being reduced to powder, it forms, when kneaded up with

water, what is called Plaster of Paris (gypsum being largely quarried near Paris), of which images, cornices, and other such things are made.

68. Beds of red or variegated sandstone occasionally lie between the Magnesian Limestone and the next important group of strata, which bears the name of the *Shell Limestone*, from its containing an unusual quantity of the remains of shell-fish. This group is remarkable as containing the remains of reptiles, of what would now be considered monstrous forms and habits. There are some traces of this class of animals in the Carboniferous Formation, and one reptile skeleton is stated to have been found in the Old Red Sandstone; but now fossils of this order become abundant. One of the reptiles here presented to us for the first time—named the *Ichthyosaurus*,



Skeleton of Ichthyosaurus.

or fish-lizard—was about thirty feet long, with the body of a fish, four paddle-fins to make its way through the water, and a large mouth like that of a crocodile. Another, the *Plesiosaurus*, was equally large, and somewhat similar, but with a long flexible neck like that of a swan. Low marshy land, with a hot moist atmosphere, is what would suit such creatures; and such, accordingly, is supposed to have been the state of much of the surface of the earth at the time they lived.

69. Next occur, mixed with limestone and sandstone, masses of *Rock Salt*, which, in some parts of the world, as in the west of England and in Prussia, are dug for the purpose of supplying that necessary of life to the inhabitants. Above the New Red Sandstone and Magnesian Limestone series occurs a set of limestone and sandstone beds, which pass by the general name of the *Lias Group*. Lias is a corruption of the word layers: the rocks it is specially applied to are of a clayey kind, and contain an extraordinary quantity of fossil fish and shell-fish, and also of the remains of the Ichthyosaurus and Plesiosaurus. The principal beds in the Lias Group are known by the names of Lias Limestones and Alum Shale; the latter being the rock from which the pure crystallised alum is extracted.

70. A series, next above the preceding, consisting of beds of limestone, sandstone, clay, and marl, obtains the name of the *Oolitic Group*, from one particular kind of bed, conspicuous in it, which is termed *oolite*, in consequence of its being composed of minute *egg-like* grains. A fragment of oolite resembles a piece of the roe of a fish, and hence one kind of it is called Roestone. This group contains vast quantities of fossils, of the kinds above described.

71. The next group consists of beds of bluish clay, green-sand, and chalk. It is known by the name of the *Chalk* or *Cretaceous Group*, from *creta*, Latin for chalk. Chalk is a well-known limestone rock composed of the earth of lime and carbonic acid; it varies from a bluish to a pure white colour, and contains layers of Flint. Flint occurs in nodules from the size of an egg to that of a man's head; these are ground down for the manufacture of china and other purposes.

72. Although rocks are deposited above each other invariably in this order, it is in few places that all these groups are to be found. In the greater part of the surface of Scotland, there are no rocks above the coal-beds. In a large portion of England, there are rocks as high as the chalk, besides a few of the still higher strata afterwards to be noticed. In the most of places, many of the strata are omitted, such never having been formed there; but, as has been already stated, no one class of rocks is ever found *below* any other rocks which it is here described as *above*. The chalk, for instance, is never found beneath the new red sandstone, nor the coal beneath gneiss or mica-slate. It is of great importance to know these facts, because they enable us to ascertain in what places valuable rocks, such as coal, may probably be found by digging, and in what places they cannot be found. When people were ignorant of the *order* of the rocks, they used to spend vast sums of money in seeking for coal where it did not exist.

73. As the groups of strata are generally of great thickness, it would have been impossible, in many parts of the earth, to reach any of the lower rocks, if they had remained in the places and positions in which they were at first deposited; and thus many of them would have been quite useless. But the forces which heaved them up from the bottoms of seas have thrown portions of the connected beds into sloping postures, so that in most places strata, originally deep in the bowels of the earth, are brought comparatively near to the surface, and, in some cases, exposed in cliffs to the open air. Masses of connected strata are also found, in some places, to

have been rent right across the direction of the seams, and one part raised higher than the other, as if we were to cut through a number of slices of bread, and lift the one pile an inch or so above the other, in which case no one edge of a slice would be opposite that from which it was cut. A derangement of this kind in the position of strata is called a *hitch* or *fault* (see fig. in p. 22). The crack or space between is often found to have been filled up by some other substance, which, from its upright wall-like appearance, is called a *dike*. Miners, in digging a bed of coal or other rock, are often stopped by these hitches, and spend much time and labour in finding where the seam is continued. Nevertheless, hitches have various and great advantages. They often bring the coal-beds nearer to the surface; they throw them into sloping positions, and thus the water which accumulates in mines is carried to a lower level; and being generally composed of firm clay, they prevent the further passage of the water, which is either brought to the surface in springs, or pumped by artificial means.

74. The heaving or elevating cause appears to depend on the expansion and bursting forth of fire from the interior, where the materials of the Unstratified Rocks exist in a melted state. In many places, this melted matter has been thrown up along with the fragments of the Stratified Rocks, for it is often found strangely mixed with them. It seems to have in some cases run into chinks or breaks, which it made in the sedimentary rock in heaving it, and sometimes it has poured over above, and covered it. When Unstratified Rock has come into existence in this way, it is said to be VOLCANIC. It then bears appearances somewhat different from granite in its original condition. The principal varieties of Volcanic Rock are *Trap*, *Basalt*, and *Porphyry*. In their structure, there are sometimes remarkable peculiarities, certain parts being in neat angular forms, like the crystals in a mass of sugar-candy. The island of Staffa, in the Hebrides, and the Giant's Causeway, in the north of Ireland, are specimens of basalt, in the shape of angular columns or pillars, neatly joined together. Arthur's Seat, Salisbury Crags, and the rock of Edinburgh Castle, are specimens of trap-rock. A hill near Glasgow, used as an ornamental burial-ground, is composed mainly of sandstone; but through the centre, the trap, when in a melted state, has forced its way, and spread itself all over the sandstone in the form of an umbrella. In these volcanic processes, as well as in all the other arrangements of the earth's surface, we can trace Almighty wisdom and goodness; they have produced that diversity of hill and valley so necessary to vegetable and animal

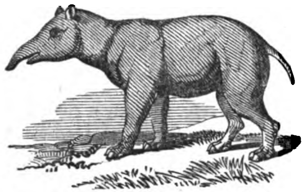
life, and brought up to the surface those rocks and minerals on which man has so much of his dependence.

75. While the lowest sedimentary rocks were at first called *Primary*, all above the Old Red Sandstone to the Chalk inclusive were for a long time classed as *Secondary*, the intermediate being named Transition, as shewing a passage from the characters of the one to the other. These names are now little used, as it has been thought best to classify rocks with a regard to the character of the fossils. Thus all up to the New Red Sandstone are now called PALÆOZOIC, as containing animals of ancient and obsolete characters; while the next groups to the Chalk inclusive are styled MESOZOIC, as implying life of a middle character between the *Palæozoic*, on the one hand, and the CAINOZOIC, or recent, on the other.

76. At the time when the great chalk-deposit, the last of the Secondary Rocks, was formed, it would appear that a very great unevenness of surface had been produced by the upheaving forces. What is now the continent of Europe, is supposed to have then been a cluster of islands, with great channels and seas lying between. At this stage, there appears to have commenced a new series of deposits, occupying the troughs or hollows lying between the elevated parts of the solid surface. Paris and London are situated above deposits of this kind. The general name of the TERTIARY FORMATION, or CAINOZOIC, has been given to these deposits.

77. The lowest beds of the Tertiary Formation are of *Plastic* or *Soft Clay*, in which are found, for the first time in the series of rocks (with a trifling exception), remains of fresh-water shell-fish. The next beds are of a *Hard and Coarse Limestone* (called, by the French, *Calcaire Grossier*), containing remains of marine shell-fish. A third group is composed of beds of *Silicious* (that is, flinty) *Limestone*, *Gypsum*, and *Marine Marls*. In the gypsum of this group, as dug near Paris, the first land-quadrupeds are found. The globe, when this gypsum was formed, had for the first time become fit for the residence of creatures superior to amphibious reptiles. These land-quadrupeds chiefly belong to an order which naturalists call *Pachydermata* (meaning *thick-skinned* animals), of which the elephant, rhinoceros, and common pig are familiar specimens now existing; but the quadrupeds of the gypsum strata, though of this order and general character, are of *species* which do not now inhabit the earth. They are, in general, of great bulk and peculiar forms. One of the most abundant of these is the Palæotherium, several species of which, varying from the size of a hog to that of a rhinoceros, have been found in the gypsum quarries of Paris, and the fresh-water deposits of the

Isle of Wight. It is allied to the Tapir in form, and seems to have been furnished with a prehensile upper lip or trunk, something akin to that of the elephant. In the same rocks are found great quantities of the fish and other creatures which had previously existed. The next beds upwards are *Sandstones* and *Marls*, with marine remains. The next and last group contains beds of silicious rock, from which millstones are made, with some marly beds; these appear, from the remains, to have been of fresh-water formation. Three of the Tertiary groups shew fresh-water remains, while two between shew those of a salt-water kind; whence it may be inferred that the ground was alternately covered with inland lakes and seas during the formation of those beds. In the earlier Tertiary strata, only three out of a hundred of the shell-fish remains are of kinds now existing. In the higher strata, there are eighteen; and in the highest of all, above ninety, out of the hundred, which still exist. The increase of existing kinds of shells is accompanied, in the higher Tertiary strata, by the extinction of the animals found in the gypsum, and the commencement of animals of the same order, but of existing species, as the elephant, rhinoceros, and hippopotamus; and also of Ruminant (cud-chewing) animals, as oxen and deer. It would thus appear that, during the deposition of the Tertiary Rocks, the earth was gradually advancing to the condition in which we now find it.



Form of Palæotherium.

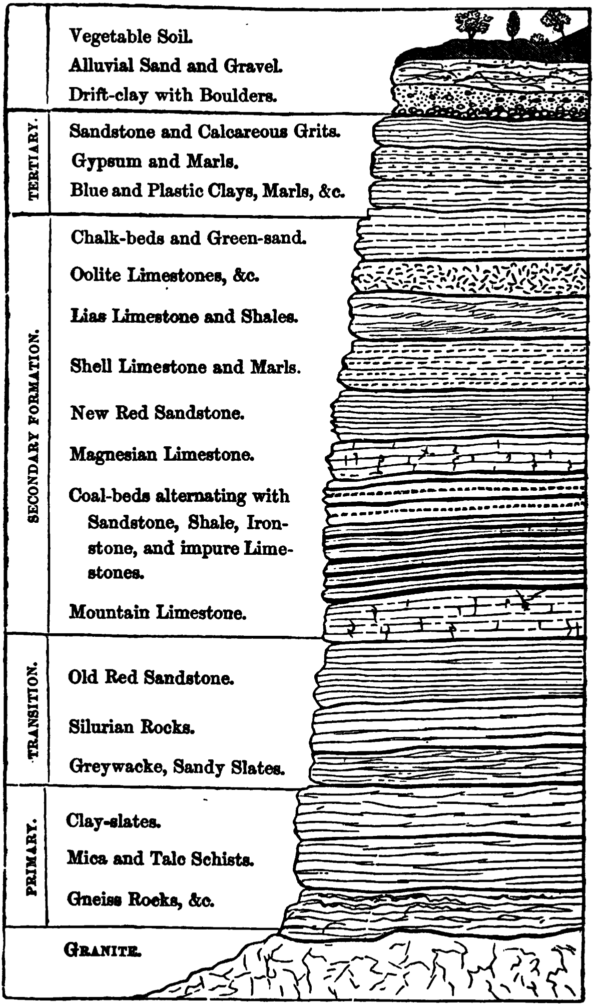
78. The deposition of the various rocks must have been a slow process, and it is therefore evident that, from the first forming of the globe to the completion of the Tertiary Rocks, an immense space of time must have passed, probably many hundreds of thousands of years. During all this time it contained no human beings, and scarcely any of the quadrupeds or birds which now exist; indeed, it must have been a globe for many ages, before even shell-fish began to live upon it.

79. After the Tertiary Rocks were formed, the earth seems to have become a scene of frequent and violent inundations, which wore away great quantities of clay, and broke off vast masses of rock, from various places, and spread the whole together over the surface. These masses of clay, sand, gravel, and pieces of rocks are generally known by the name of

SUPERFICIAL ACCUMULATIONS. The lowest and most extensive of these is a bed of hard blue clay, mixed with stones of various sizes, often rounded, smoothed, and scratched. It is found in many parts of the world, and bears the name of *Drift*, from the materials having evidently been transported from considerable distances. It is most probable, from various appearances, that this bed was formed by the action of ice, more or less water-borne, or mixed with water. Above the Drift, there are often found beds of *Sand* and *Gravel*, such as are still laid down on the beaches of seas; these places must have accordingly been covered by quiet or ordinary seas at a comparatively recent period. In some places, along the courses of rivers, there are flat valleys, composed of sand, gravel, and other light materials. All of these have been formed by the stuff carried down by the rivers from higher grounds. The soil of these places is called *Alluvium*, and the valleys themselves are said to be alluvial—that is to say, composed of matter washed together by the ordinary operations of water. In England, such places are usually called *meadows* and *dales*, and in Scotland are known by the name of *carses* and *haughs*.

80. Besides these, there are other superficial accumulations now in process of formation. Large sandy tracts are forming along some parts of the sea-shore, known by the names of *downs* or *links;* and the mud of rivers is creating alluvial land, oftentimes to vast extent, as the *Deltas* of the Nile and Ganges. In most marshy places, certain kinds of plants spring up in great abundance, and the yearly accumulations of their stems and leaves form *peat;* while in such seas as the Pacific, *coral reefs* and islands are formed by the coral insect from limy matter, which it collects from the water of the ocean. On the surface of the dry land, in most situations, we find the *Vegetable Soil*, generally a mixture of decomposed rock with decayed animal and vegetable matter. According as the rocks lying below are silicious, clayey, or calcareous, the soil at the place is, generally speaking, of a similar character; and each kind of soil has peculiar properties fitting it for rearing particular kinds of plants. Hence the value of land depends much on the kind of rock which prevails nearest to the surface.

81. The annexed table is intended only to shew the order of rocks, from the first and lowest, upwards to the most recent and superficial. There is also an engraving to exhibit a specimen of the arrangements in which Unstratified and Stratified Rocks are actually found, as they would appear if they were cut through vertically, so as to allow of our having a side-view of them.


Vegetable Soil.
Alluvial Sand and Gravel.
Drift-clay with Boulders.
TERTIARY.
Sandstone and Calcareous Grits.
Gypsum and Marls.
Blue and Plastic Clays, Marls, &c.
SECONDARY FORMATION.
Chalk-beds and Green-sand.
Oolite Limestones, &c.
Lias Limestone and Shales.
Shell Limestone and Marls.
New Red Sandstone.
Magnesian Limestone.
Coal-beds alternating with Sandstone, Shale, Iron-stone, and impure Lime-stones.
Mountain Limestone.
TRANSITION.
Old Red Sandstone.
Silurian Rocks.
Greywacke, Sandy Slates.
PRIMARY.
Clay-slates.
Mica and Talc Schists.
Gneiss Rocks, &c.
GRANITE.

SECTION OF EXISTING ARRANGEMENT OF ROCKS.

In the above section, the UNSTRATIFIED ROCKS appear in hills and irregular disrupting masses, from the older granite to the active volcano. The STRATIFIED occur in their regular order. The *Primary* slope from the side of a lofty granitic mountain at a steep angle, and in bent or contorted strata; the *Transition* lie between the ranges of less elevated mountains; the *Secondary* occupy a still less elevated position, the Mountain Limestone being raised up on the hillside, with the coal-beds thrown into basin-shaped hollows, or broken up by faults, and the Magnesian Limestone and Chalk rising up into slight eminences; the *Tertiary* lie in basin-shaped strata; and the *Superficial Accumulations* occur either as sandy downs by the sea-shore, or as diluvium, with boulders overlying the earlier formations. The pupil will perceive how the Tertiary strata are said to be above the coal-beds, though they do not overlie them; and how the coal-beds are above the Transition rocks, though removed from each other by a wide extent of country. The lowest strata being formed first, he will also understand why coal is said to be of more recent origin than clay-slate, and chalk younger than coal.

82. The Primary, and some of the Secondary Rocks, contain numerous rents or veins, which are filled with substances of a different kind from the rocks. In some there are *ores*, from which, by particular processes, we derive the metals used so extensively in the operations of life. Of the metals, the most useful are platinum, gold, silver, quicksilver, copper, iron, lead, tin, zinc, and antimony. In the Primary and Unstratified Rocks, we also find those stones which, from their beauty and rarity, have been called *precious*. The chief of these are the diamond, the garnet, the ruby, the sapphire, the topaz, the emerald, the beryl, the agate, the jasper, and the amethyst. The crust of the earth contains a great number of other mineral substances, each of which is found more frequently in connection with one stratified group than with another. The minerals most *useful* to man are building and paving stones, slate, limestone in all its forms from marble to chalk, coal, ironstone, rock-salt, flint, and clay for the manufacture of bricks and pottery.

83. The structure and composition of the earth's crust is the subject of the science of GEOLOGY, so called from the Greek words *ge*, the earth, and *logos*, a discourse. To observe and describe the mineral ingredients contained in the earth's crust, is the object of MINERALOGY. The science of searching for and working the useful minerals is called *Mining;* and the art of extracting the metals from their ores, *Metallurgy*. The science which enables men to turn the soil to best advantage in rearing food is called AGRICULTURE, from the Latin *ager*, a field, and *colere*, to till.

CRUST OF THE EARTH.—This term is employed to express that outward portion of the globe which is composed of rocks, minerals, earths, &c. The distance between the surface and centre of the globe is about 4000 miles; and as the solid covering may extend to a very small fraction of this depth, the term *crust* has been used to draw a distinction between the outer parts which we know, and the interior parts of which we can only form a conjecture.

SYENITE—so called from Syena, in Egypt, where this rock is found in abundance. It differs from common granite in being composed of quartz, felspar, and hornblende, instead of quartz, felspar, and mica.

MICA AND TALC.—These are transparent glistening minerals, so transparent, that they are substituted for glass in some parts of Russia. They are occasionally found in large crystals, which can be split up into thin plates; when disposed in small scales, they give the slaty character to those rocks called mica and talc slates.

AMMONITE—(*Ammon*, an Egyptian deity, represented with a ram's head) a fossil shell-fish, so called from its resemblance to a curled-up ram's horn.

TRILOBITE—from its body being composed of *three lobes*.

ICHTHYOSAURUS—from the Greek *saurus*, a lizard, and *ichthys*, a fish; so called from its uniting the form of a lizard with the habits of a fish.

PLESIOSAURUS—Greek *pleisson*, most or nearest; more nearly resembling a lizard than the ichthyosaurus.

PALÆOTHERIUM—from the Greek *palaios*, ancient, and *therion*, a wild beast; the ancient wild beast. The termination *therium* is very commonly applied to fossil mammalia of the Tertiary strata; as, for example, Megatherium, the great wild beast; Anthracotherium, &c.

DELTA—generally applied to tracts of alluvial deposits formed at the mouth of rivers, from the alluvial land of the Nile, which resembled in shape the Greek letter Δ, or *delta*.

OOLITE—from the Greek *oon*, an egg, and *lithos*, a stone; so named from the resemblance of the stone to the roe or eggs of a fish. *Lite* is a common termination in geology, which the pupil should remember.

SILICIOUS—from the Latin *silex*, flint; flinty, or composed of grains of quartz. Sand is chiefly composed of quartz grains; hence sandy soils are said to be silicious.

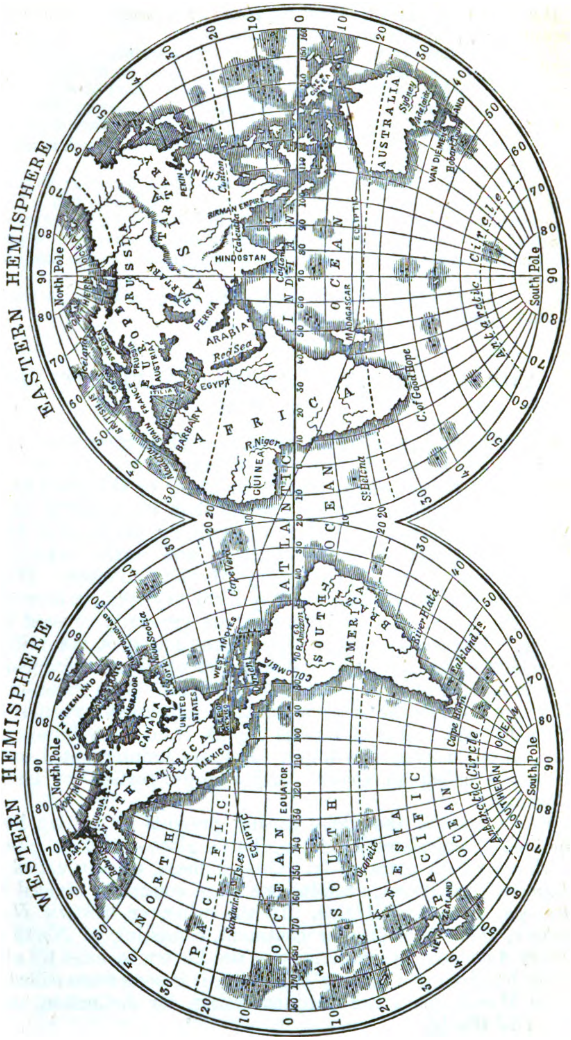
CALCAREOUS—from the Latin *calx*, lime; limey, or having a portion of lime mingled up with its substance.

THE EARTH—ITS GENERAL SUPERFICIAL FEATURES.

84. The earth, as already stated, is a globe measuring about twenty-five thousand miles in circumference, but a little flattened at either pole, so that its diameter or thickness at the equator is twenty-six miles greater than its diameter at the poles. The substance of its outer part, or *crust*, is solid, being composed of various kinds of rocks and earths, which are elevated and depressed in a very irregular manner. Where these rise to a certain height, they form dry land; where they sink into depths and hollows, they are generally covered with water. This surface contains, in round numbers, 200 millions of square miles, nearly three-fourths of which are occupied by water, leaving only one-fourth of dry land. This great extent of water is called the *Sea;* it forms an extremely irregular line with the land, and is of various depths, from a few fathoms, to two, three, or even five miles. A large uninterrupted extent of sea is called an *Ocean;* and a large portion of land, a *Continent.*

85. A map of the globe usually presents it in two hemispheres—hemisphere signifying half a globe—so as to give us a view of both sides of it. One of these, usually called the *Eastern Hemisphere*, contains one large continent, divided into *Europe*, *Asia*, and *Africa*. In the other, or *Western Hemisphere*, there is a smaller continent, consisting of *North* and *South America*. As America was not known to exist till about three hundred and seventy years ago, it is sometimes called the *New World*, the other continent being, for distinction, called the *Old World*.

MAP OF THE WORLD.



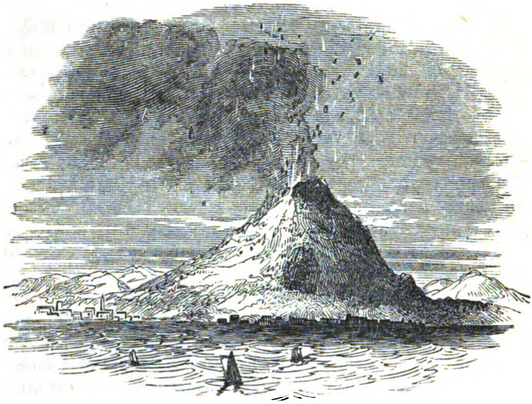
86. A large extent of sea is called an *Ocean*. America is divided from Europe and Africa by the *Atlantic Ocean*, which is between two and three thousand miles broad. America is divided from Asia by a still larger sea, the *Pacific Ocean*, which is above five thousand miles in breadth. To the south of Asia there is another great sea, named the *Indian Ocean;* and in the neighbourhood of the poles are great seas, respectively called the *Northern* and *Southern Oceans*. Portions of land which are small in comparison with the seas which surround them, are called *Islands;* an island being a general term for any piece of land surrounded by water. The largest island is Australia, to the south of Asia; and amongst the most important of the rest, are Borneo, Tasmania, Ceylon, Madagascar, Sicily, Great Britain, Ireland, and Iceland, in the eastern hemisphere; the West India Islands, New Zealand, and the Sandwich Isles, in the western hemisphere. A portion of land nearly surrounded by water is called a *Peninsula;* and the narrow neck which connects it with the continent or mainland, an *Isthmus*. A point of land jutting out into the sea is called a *Cape* or *Promontory*.

87. A smaller extent of water is called a *Sea*. The Mediterranean, the Baltic, the White and Red Seas, are familiar examples. A bend of the sea into the land is called a *Bay* or *Gulf;* a narrow connecting piece of sea, a *Strait* or *Channel*.

88. The surface of the land is in general very unequal. In some places, there are plains little above the level of the sea; in others, there are hills and lofty ranges of mountains. Extensive plains are known as *steppes*, *prairies*, *pampas*, or *savannahs;* smaller ones as *valleys*, *straths*, or *dales*. Elevated land is spoken of as rising into *hills* and *mountains*. A tract of high and mountainous ground stretches from the north-eastern extremity of Asia almost directly to the southern extremity of Africa. This tract embraces the Altaï, the Himalaya, the Abyssinian Mountains, and other ranges. Another similar tract stretches north and south from one end of America to the other. This tract embraces the Andes in South America, and the Rocky Mountains in North America. The principal mountain-ranges, besides the above, are the Alps, to the north of Italy; the Pyrenees, between France and Spain; the Uralian Mountains, between Europe and Asia; the Dofrafields, between Sweden and Norway; the Cheviots, between England and Scotland; and the Grampians, in the north of Scotland. Comparatively few mountains are a mile in height. The highest is a peak of the Himalaya in Asia, which is 28,000 feet, or about five miles.

89. Some hills have openings or *craters* at the top, from

which they occasionally throw up burning matter or lava, together with stones, ashes, and, in some instances, mud. There are above two hundred such hills: the most remarkable in Europe are Etna, in Sicily; Vesuvius, in Italy; and Hecla, in Iceland; but the west side of America contains more than all the rest of the earth. They are evidently the mouths or vents



View of Mount Etna.

of subterranean fire. They are termed *Volcanoes*, from the heathen deity Vulcan (the god of fire), who was supposed by the ancients to reside under Mount Etna, engaged in forging thunderbolts for Jupiter.

90. It has been stated that the parts of the earth near the equator are the warmest, in consequence of the rays of the sun falling on the earth most directly in those parts. A belt or zone surrounding the earth between the tropics, and every part of which is liable to be twice a year exposed to the sun's vertical rays, is termed the *Torrid Zone*, on account of the great heat which prevails there. The two similar belts between the tropics and the arctic and antarctic circles are termed the *Temperate Zones*, because the heat of the sun is there more moderate. The remaining parts of the earth, where the sun's rays slant very much, and consequently give little heat, are termed the *Polar Regions*. We see the effect of the more direct falling of the sun's rays in gardens sloping to the south. These always produce fruit earlier than gardens

which slope to the north. It is supposed that, when the rays of the sun slant at an angle of forty degrees (or nearly midway between perpendicular and horizontal), they lose half their power. Some other circumstances affect temperature. Places elevated considerably above the level of the sea are colder than places in a low situation. Hence, the tops of some mountains, even in temperate and tropical countries, are constantly covered with snow. This height is called the *snow-line*, and is found at an elevation of 16,000 feet in the tropics, while in Britain it is only 5000. The thermometer (an instrument for measuring heat, which will be afterwards explained) falls a degree for every ninety yards we ascend. In the neighbourhood of seas, there is less variation of heat than in inland places. On account of various such circumstances, the average winter temperature of Milan and Edinburgh, for example, is the same, although Edinburgh is almost one-half further from the tropical region than Milan is.

91. The surface of the earth is almost everywhere covered by vegetables of various kinds, either growing spontaneously, or cultivated by the hands of men for sustenance and other useful ends. It is essential to the growth of vegetables that they should enjoy heat, light, and moisture. The sun gives them heat and light directly by his own rays: moisture he raises into the atmosphere, where, in the form of clouds, it remains, till, in obedience to certain laws, it descends in rain. The rain soaks the earth, so as to enable it to communicate sap to the vegetables. Much of it also sinks below the surface, to rise in lower levels in the shape of *springs*. Whatever is not taken directly back in vapour, or otherwise used, collects in channels and hollows, in the forms of *rivers* and *lakes*, and ultimately flows back to the sea. And thus more than one important end is served; for not only are the fruits of the earth brought to maturity, but the streams and rivers in their courses supply water for the sustenance of the people living near them, furnish the means of driving machinery, and, when they amount to a great quantity and depth, allow of ships being brought far into the land, for the carriage of goods and transport of passengers.

92. The various parts of the earth present, in general, the plants and animals appropriate to the prevailing temperature. The shrubs and trees which grow in the torrid zone are, in general, more luxuriant than those of more temperate climes. In the temperate zones there are many for which the torrid zone would be too hot, and the polar regions too cold. The polar regions, also, have plants fitted by their nature to grow there. Sometimes, in the torrid zone, tropical plants are seen

near the bottom of a high mountain; while the middle, being under moderate warmth, shews the plants of the temperate zones; and the top, which is always exposed to great cold, is covered with the mosses and lichens of the polar regions; so that one hill may be said to afford a specimen of all climates, and all their various productions.

93. The sea is less liable to variations of temperature than the land. It is affected by waves and currents; and also by tides, which ebb and flow twice in the twenty-four hours. Like the dry land, it is peopled with animals and furnished with vegetables adapted to its condition. Plants and animals inhabiting the land are said to be *terrestrial;* those living in sea or salt water, *marine;* and those in fresh-water lakes and rivers, simply *aquatic.* The sea is peopled only at moderate depths, and is supposed to be as void of plants and animals in its deepest parts as those lofty mountains which are perpetually covered with snow.

94. The external features of the earth, and the mode in which these affect the distribution of plants and animals, form the subject of the science of PHYSICAL GEOGRAPHY.

PENINSULA—from the Latin *pene*, almost, and *insula*, an island; that is, a portion of land almost surrounded by water.

GEOGRAPHY—from the Greek *ge*, the earth, and *grapho*, I write; a writing about, or description of the earth.

PHYSICAL—from the Greek *physis*, nature; hence physical geography relates merely to the *natural* features of the earth, without considering its *artificial* division into states, kingdoms, provinces, and cities, which form the subjects of political geography.

HEAT.

95. The well-known sensation or feeling of heat is usually confounded with what produces that sensation: we equally speak of the heat of the sun and the heat we feel in our bodies from his rays. In science, the word is properly applied only to what produces the sensation.

96. Heat, in this sense, may be described as a thing pervading all the material world, and serving very important ends therein, but the exact nature of which is not known. By some men of science, it is supposed to be a very thin and subtle fluid; by others, it is deemed only a property or affection of matter—a motion of some kind among the atoms of bodies. This last view is now considered the more probable.

97. It is a law of nature, that, when two bodies possessing different degrees of heat are brought together, the warmer

gives out part of its heat to the colder, till the two come to an equality. Thus, if we were to take a stone into our hand, the hand would give out some of its heat to the stone, till the one was reduced and the other raised so much, that both were alike warm. In this process we should feel the stone at first to be *cold*. This is owing to the departure of the heat from our hand into the stone. So, also, if we were to dip our hands, one into a vessel of very hot, and another into a vessel of very cold water, and then both together into a vessel of lukewarm water, the hand which had been in the cold water would feel warm, and the hand which had been in the hot water would feel cold; for in the one case we should receive heat, and in the other give it out. Cold is thus seen to be not a real or positive thing, as heat is, but only a sensation occasioned by a less degree of heat, or by heat going out of our bodies. Even the things which we commonly speak of as the coldest in nature, namely, ice and snow, contain some degree of heat, though a comparatively low one.

98. Some bodies receive and convey heat more readily than others. In metal tea-pots, it is customary to make the handle of wood: this is for two reasons, first, because the wood does not receive so much of the heat from the water in the tea-pot as a metal handle would do; and, second, because when it is heated, it does not part with its heat so readily to the hand that touches it, and therefore does not feel so hot. Were we to take a piece of silver, copper, lead, marble, and clay, of equal sizes, and place them upon the sole of a heated oven, the silver would soon become as hot as the oven, next, the copper, then the lead, after that, the marble, and, last of all, the clay; so that, while we could put our finger upon the clay without injury, the heat of the silver would be intolerable: silver is therefore said to be a good conductor, clay, a bad conductor, of heat. It is a common notion that woollen clothes *give us heat;* but, in reality, their utility arises from their only preventing our own natural heat from leaving us. Bodies which receive and convey heat readily are called by men of science *good conductors*, and bodies of an opposite kind are called *bad conductors, of heat.* Heat conveyed by one solid body to another is said to be *conducted;* when diffused through a liquid or through air, which takes place mostly by currents in the liquid or the air, it is said to be *conveyed;* and heat that streams off from one body to another through the air, as when the heat of the fire strikes the hand held opposite to it, is said to be *radiated*, or given off by *radiation.*

99. Sometimes a great deal of heat enters a body and disappears, as it were; that is, the body does not feel any hotter

to the touch, nor does the thermometer (see p. 46) shew it to be any hotter. Thus it takes a great deal of heat to melt a piece of ice; and yet the water just as it comes from the ice, feels as cold to the hand as the ice itself, and affects the thermometer in the same way. The heat that has entered has not warmed the ice, but only changed it from the solid to the liquid state. Heat that thus becomes insensible is called *latent* (that is, concealed) heat. A vast amount of heat also becomes latent when water rises in vapour or steam. All this concealed heat is given out again in a sensible form, when the vapour returns to the state of water, or the water to the state of ice.

100. The chief sources of heat are the sun, and the burning of fuel, or *combustion*. But there are several other ways of producing it. It may be produced by *friction;* that is, by the forcible rubbing of one body upon another. The rubbing of a smooth metallic button upon a board, by which much heat is produced, is an experiment familiar to every school-boy. Two pieces of wood can be kindled by rubbing them firmly and rapidly together; and the axles of wheels have become red hot by being allowed to run without oil. Heat may be produced by *percussion;* that is, by striking one body forcibly against another. A flint struck rapidly upon a piece of steel gives out sparks of fire, which can kindle tinder or gunpowder. A piece of iron, by smart hammering upon an anvil, can be rendered so hot as even to kindle the fire of the blacksmith. Heat may also be produced by *compression;* for no body, whether solid, liquid, like water, or gaseous, like air, can be pressed into less bulk without giving out heat. The *match syringe* is a familiar example of heat produced by the compression of air. It is an instrument consisting of a brass tube, open at one end, and a rammer exactly fitted to it, on the end of which is a piece of match or inflammable paper: when the rammer is smartly pressed down into the tube, so as to force the air into a small space at the bottom, so great is the heat, that the match takes fire. Further, heat may be produced *chemically;* that is, by the peculiar action of certain bodies upon one another. Sulphuric acid (oil of vitriol), when mixed with water, produces great heat; so does water when poured upon burnt lime. Half-dried hay or grain, when put together in stacks, frequently becomes so hot as to take fire; so ships have been sometimes set on fire by the heat produced among bales of cotton and wool. When substances take fire in this manner, it is said to be by *spontaneous combustion.*

101. Heat has the effect of keeping the particles of bodies at a certain distance from each other. This effect of heat is said

to be a *repulsion* of the particles of bodies; that is, a pushing away from one another. The hardest and most solid bodies are liable to this law; and when their heat is increased, the distance between the particles increases in proportion. Hence, an increase of heat *expands* bodies, a decrease of heat *contracts* them. When a rod of iron is put into a fire, and made red hot, it becomes perceptibly longer and thicker. A small glass globe filled with common air, if held in the flame of a candle, will burst with a loud noise; and the air in a bladder held near the fire will so expand as to tear the bladder asunder. This expansion by heat is so great in some bodies, that no force is able to resist it. Water can be converted into steam, which occupies 1700 times the space of the water; and hence the force of the steam-engine.

102. It has been stated that heated bodies radiate their heat through the atmosphere. Substances having a *black* and rough surface *absorb* and *radiate* this heat more readily than those which are *white* and smooth. If a piece of black, and another of white cloth be laid upon snow, and exposed to the sun's rays, the black will soon be found to have absorbed these rays so as to melt the snow beneath it, while under the white piece little effect has been produced.

103. A polished metal surface, such as silver or tin, both radiates heat more slowly, and also absorbs it more slowly than any other kind of surface. If two tin vessels of the same size are taken, the one bright and clean, the other black and rusty, or made rough on purpose by being coated with blacking, or even with whitening, and if both are filled with boiling water and set to cool; the bright vessel will have lost but little of its heat, when the other will be almost quite cold. And if these same vessels, filled with cold water, were set so as to receive the rays of a bright fire without touching it, the water in the rough or blackened vessel would be heated long before the other.

104. The reason why the bright polished vessel does not readily become heated when thus exposed to the fire is, that it *reflects* the rays of heat. Polished surfaces generally reflect heat. This can be easily shewn by holding a mirror or piece of polished tin opposite to a bright fire, when the rays of heat will be thrown back or reflected without making the mirror sensibly warmer, while bodies opposite to the mirror will be rendered much warmer. The rays of heat can be collected or *concentrated*, as every boy knows who has ever had a lens of glass. Sometimes lenses are constructed of such a size as to collect the sun's rays in sufficient power to melt gold and iron.

105. Heat, as a thing pervading all bodies, and keeping them all at a certain degree of expansion, may be considered as one of those elements upon which the existence of the present fabric of the world depends. If heat were suddenly withdrawn from nature, the apparently solid and compact globe would shrink into a much smaller size, and all vegetable and animal life upon its surface would instantly perish. The degree of heat in the atmosphere or in any other body is called its *temperature;* and for ascertaining this correctly, a very ingenious instrument has been invented. It is called the *thermometer*. It is a glass tube with a bulb at the bottom, into which mercury or quicksilver is put, with a scale of figures along the tube to mark the rising of the quicksilver. The atmosphere affects the metallic fluid in the bulb, and, according to its warmth, causes it to expand and rise in the tube. In the scale of figures, 32 is marked as the *freezing-point;* that is to say, when the mercury is at 32, water freezes; and the more it is below that point, the more intense is the frost. When it falls to 0, it is said to be at *zero;* at 60, the air is reckoned *temperate;* 98 is the *heat of the blood* in the average of living men; and 212 is the point at which water *boils*. Thermometers are useful for indicating the heat of apartments, and are of service in many of the arts, in which the temperature of the air, or of water or other liquids, requires to be attended to.

RADIATION—from the Latin *radius*, a ray—is that process by which heat is given off in every direction like the rays of the sun.

REFLECT—from the Latin *re*, back, and *flecto*, I bend; the rays of heat and light are said to be *reflected* by mirrors and other polished surfaces. For example, the rays of light falling from the face upon a mirror are bent or thrown back to the eye, and hence we see our own forms reflected.

REPULSION—from the Latin *re*, back, and *pulsus*, driven or thrust—is that property derived from heat by which the particles of bodies thrust each other asunder. Particles so affected are said to be *repelled*.

THERMOMETER—from the Greek *thermos*, heat, and *metron*, a measure; a measurer of heat, or CALORIC, as heat is sometimes called, from the Latin word *calor*, heat.

FROST—SNOW—ICE.

106. When the heat of the air falls below the freezing-point, which it does principally from the weakness of the sun's rays in winter, the phenomenon of frost, or freezing, ensues. Freezing is a process by which water is changed into *ice*.

When the heat of the air rises above the freezing-point, the ice begins to melt. In freezing, water expands or swells into a greater bulk, and in so doing, it often bursts vessels, and even breaks up great pieces of rock in which it may have been confined. Ice is about one-ninth lighter than water, and hence it always floats on the surface. It frequently accumulates in vast masses in the polar seas, and is then known by such names as *icebergs*, *floes*, and *ice-islands*. In lofty regions, and on the tops of mountains, where the temperature seldom or never rises above the freezing-point, ice and snow also accumulate in large masses; these masses are known by the name of *glaciers*. Fragments of them, called *avalanches*, sometimes descend with great violence into the valleys below, destroying trees, herds, and cottages.

107. When the heat of the air is below the freezing-point, vapours become frozen, and fall to the earth in the form of *snow*. Rain-drops, frozen in their descent through a cold portion of the atmosphere, form *hail*. When the descending flakes of snow come into a temperature above the freezing-point as they approach the earth, they are apt to melt, and, in such a case, fall in the shape of *sleet*, which is half-melted snow. Dews, frozen as they are deposited, make *hoar-frost*.

108. Snow is almost always of a dazzling white colour. When it accumulates on the ground in winter, it is useful in keeping the earth at a moderate degree of cold; for, where the snow lies, the temperature of the ground beneath seldom descends below the freezing-point, which is by no means severe. The germs of vegetation are thus kept alive in certain cold countries, where they would otherwise perish.

109. All liquids do not freeze at the same temperature. For example, olive-oil freezes at 50, water at 32, milk at 30, and quicksilver not till the temperature is so low as 39 degrees below zero. There are several artificial modes of producing intense cold, just as there are of producing heat. The most common method is by what are called *freezing mixtures;* pounded ice and common salt, or new-fallen snow and salt, is such a mixture, and will reduce a thermometer placed in it several degrees below zero. These mixtures are used for cooling wines and liquors, and also by chemists in some of their preparations.

GLACIER—from the Latin *glacies*, ice—applied to accumulations chiefly of ice formed on lofty mountains.

AVALANCHE—from the French *avaler*, to let sink—a mass of snow, or of snow and ice, which falls from the side of a mountain.

LIGHT.

110. The nature of light, like that of heat, is a subject of doubt among men of science. It was at one time supposed to be, like heat, an extremely thin and subtle fluid; but the more general opinion now is, that it is produced by a particular agitation in a fluid, too thin and light to be perceived by the senses, but which is supposed to extend through all space, and to which the name of *ether* has been given. Some of the laws under which light operates have been better ascertained.

111. Astronomers, having found that a brief interval elapsed between the time when they had calculated upon seeing Jupiter's satellites emerge from behind his body, and the moment when they actually did make their appearance, were led to suppose that light required some time to *travel* through space. On investigation, it was discovered that its speed was at the rate of a hundred and ninety-two thousand miles in a second; consequently, that the light of the sun must take eight minutes to reach our earth.

112. Light is said to *radiate* from a luminous object, and to proceed in straight rays. Bodies which allow these rays to pass through them, such as glass, are said to be *transparent;* those which arrest or intercept them, are termed *opaque*. The surfaces of opaque bodies *reflect* light; that is, throw it back. The moon, for instance, reflects the sun's light. When surfaces are smooth and clear, they are particularly adapted for reflecting light, and on this depends the power of a mirror to shew us a copy of our own image, or the image of any other object presented to it. Insubstantial as light appears to be, and perhaps is, it observes one of the laws of matter in its reflection, for it strikes a surface and returns from it at the same angle, just as a ball does when thrown against a wall.

113. Light passing through transparent bodies of uniform density proceeds in straight lines; but when it passes through bodies of different densities, its rays are turned off the straight line. Thus, air and water are of different densities; and hence, if we dip a straight rod into water, the portion in the water will appear to be slightly bent upwards. It is this circumstance which causes a pool of water to appear one-fourth less deep than it really is—a fact which it may be of importance to remember, as it may prevent people from rashly venturing into water beyond their depth. Rays turned off the straight line by passing from a rarer to a denser medium, or from a denser to a rarer, are said to be *refracted*. The refractive power of

different media is unequal; though, generally speaking, it may be said to be nearly according to their densities.

114. If rays of light are made to pass through a triangular piece of glass or other transparent substance, they are found to be changed from their usual pure and clear state into seven colours shading into each other—namely, red, orange, yellow, green, blue, indigo, and violet. A piece of glass constructed for this purpose is called a *prism*, and the appearance produced is known by the name of the *prismatic spectrum*. A person standing between the sun and a falling shower sees the same effect produced on the opposite side of the heavens in the shape of a *rainbow;* it is also produced when the sun shines upon the spray of a water-fall or the steam of a steam-engine. This separation of light into various colours is caused by the different degrees of refrangibility; the red being the least, and the violet the most refrangible. A mixture of all these colours produces white; red and yellow form orange; yellow and blue form green; and so on with the rest; a mixture of any two always producing that between them.

115. Light is also a powerful chemical agent in nature. It is the cause of the green colour so prevalent in vegetables; without it they become white and sickly, do not acquire a woody consistency, and never ripen. Most persons are familiar with the process of blanching celery by earthing it up from the light; or have seen the white and tender stem of a potato which has sprung in a dark cellar. Light is also supposed by men of science to have a similar effect upon animals; those of exposed and sunny climates coming sooner to maturity. Many metallic substances change colour, or become black, on being exposed to light—such as marking-ink, which is a preparation of silver—and dead vegetable matter in general becomes white. This effect of light upon cotton and linen cloth in the process of bleaching is too well known to be described. It is through the chemical effects of the rays of light that it can be made to draw pictures of things, called *photographs*.

116. The rays of light proceeding from bodies, or reflected from their surfaces, impress the eye with the sensation of light; and hence all the phenomena of *sight* or *vision*. The properties of light, and the various circumstances connected with vision, form the subjects of the science of OPTICS.

LUMINOUS—from the Latin *lumen*, light; any body from which rays of light proceed are said to be luminous, or light-giving.

TRANSPARENT—from the Latin *trans*, through, and *pareo*, I appear; objects which permit light to pass, or be seen through them, are transparent. Glass is a familiar example.

OPAQUE—from the Latin *opacus*, dark—is the reverse of transparent, and applied to bodies through which light does not pass.

REFRACTION, REFRANGIBILITY—from the Latin *re*, back, and *frango*, I break, *fractus*, broken; rays or lines of light are said to be refracted when they appear to be broken or thrown aside off their usual straight course.

PHOTOGRAPH—from the Greek *phos*, *photos*, light, and *grapho*, I write; a picture made by light. The art of taking such pictures is called Photography.

ELECTRICITY AND MAGNETISM.

117. It was observed in ancient times, that, when amber was rubbed, it acquired a power of attracting or drawing towards it such light bodies as hair and feathers. They called this power electricity, from *elektron*, Greek for amber. At a more recent period, amber, and some other bodies, such as wax and glass, were found to give out, when rubbed, bright sparks or jets of light, as if a luminous fluid were issuing from them. As in the case of light and heat, it is not known what electricity is in itself—whether it is an actual fluid, or only an affection of the bodies that seem to give it out. The latter opinion is now thought the more probable; but for explaining the laws under which it operates, it is more convenient to speak of it as a fluid.

118. Electricity, like heat, appears to pervade all material things. Like heat, also, it exists in a certain ordinary proportion in each body. It is not then palpable to our senses. By particular operations, a body may be overcharged with it; that is, have more than its ordinary proportion. A piece of glass, when rubbed, becomes thus overcharged, by taking it from the cloth with which it is rubbed. But a body overcharged with electricity, like a body possessing more than its ordinary degree of heat, is liable to discharge the excess into some neighbouring body, so as to return to its usual condition. In the language of men of science, electricity has a tendency to keep in *equilibrium* or *balance* in all bodies. It is when thus collected in unusual quantities in any body, and extending itself into others, that it takes the appearance of a fluid.

119. When a body has more than its ordinary share of electricity, it is said to be *positively* electrified. But a body may also, by certain circumstances, have less than its share, as the cloth with which glass has been excited; in which case, it is said to be *negatively* electrified. Instead of speaking of positive and negative states of electricity, some consider that there are two distinct kinds of electricity; the one that which exists in a piece of glass when rubbed, and which is therefore

called *vitreous;* the other, what exists in a piece of wax when rubbed, and which is called *resinous*. The difference between these two kinds of electricity, or between the positive and negative states of electricity—for it is of little consequence which view we take—will be understood by the following experiments, which any one may easily make for himself: If we suspend a small ball of pithwood by a dry silk thread, and apply to it excited glass and wax alternately, the following phenomena take place. The excited glass-rod, on being brought near to the ball, attracts it; and if the glass be gradually removed, and again brought near to the electrified ball, the ball is repelled, instead of being attracted. The same alternate attraction and repulsion take place when we excite a stick of sealing-wax, and apply to it the ball. But if, when the ball has been electrified by the glass, we apply the excited wax, the ball, instead of being repelled, is attracted; and so also when the ball has been electrified by the wax, the glass, instead of repelling, attracts it. Hence it follows that,

Excited glass *repels* a ball electrified by excited glass,
Excited wax *repels* a ball electrified by excited wax,
Excited glass *attracts* a ball electrified by excited wax, and
Excited wax *attracts* a ball electrified by excited glass.

120. It is to be borne in mind, then, that the names *vitreous* and *positive* are used to signify the same thing—namely, that particular kind of electricity or electrical state manifested by excited glass; and that *resinous* and *negative* also signify the same thing—namely, that particular kind of electricity or electrical state manifested by excited wax.

121. Machines have been constructed for collecting electricity, and shewing it in a palpable form. A glass cylinder or wheel is made to revolve against a cushion covered with a mixture of tin and quicksilver. The electricity produced by the friction or rubbing pours in a stream into a phial coated with tin-leaf. From this phial it can be drawn by the knuckle into our own bodies, which, in receiving it, experience a shock or twinge, especially along the arms. The electricity contained in one phial produces but a slight shock; but when many phials are joined together, a shock is produced sufficient to knock down an ox; and the heat produced by the spark is so intense as to melt the hardest metals. A combination of such phials or jars is known by the name of an *Electrical Battery*.

122. When a body is excited, or *charged* with electricity, if a rod of metal is made to touch it or held near it, the electricity will run along the rod, and pass through the hand to the ground; but if the rod is of glass or of wax, the electricity will not pass. Hence metals are called *conductors*, and glass

and wax, *non-conductors*. The best conductors in their order are, the metals, charcoal, acids, water and most liquids, living vegetables and animals (from their sap and blood consisting mostly of water). The best non-conductors are gutta-percha, amber, resins, sulphur, wax, glass, silk, hair, feathers, dry air, and other gases. Owing to water being a good conductor, any substance when wet or damp becomes a conductor. An electrified body supported by glass or any other non-conducting substance, and surrounded by dry air, is said to be *insulated*, because its electricity is cooped up, as it were, on an island (in Latin, *insula*), and has no way of escape.

123. During hot weather, the air becomes overcharged with electricity, so as to be exactly in the condition of a phial charged by an electrical machine. The disposition to regain its usual condition, or to be restored to equilibrium, then causes the electricity to be exhibited on a very grand scale, flashing from cloud to cloud, or darting into the negatively electrified ground, accompanied by tremendous explosions, and endangering the lives of those who are near it. This manifestation of electricity is known by the name of *Lightning*, and the sound of the explosions by that of *Thunder*. The phenomenon of thunder was supposed in ignorant ages to be the voice of an offended Deity, but is now known to be a natural process which has the effect of restoring the air to a healthy state, and it must therefore be considered as a proof of the divine goodness.

124. In descending to the ground, the electricity or lightning is apt to damage churches, houses, and other buildings, and to hurt or destroy those who may be within them. To prevent such evils, a rod composed of metal (metal being a *Conductor*) may be fixed upon the building, rising above it in a spike, for the purpose of attracting the lightning, and descending by the outside of the wall to the ground below, for the purpose of carrying it off into the earth. The rapidity with which electricity can be conducted along metallic substances, has suggested the idea of employing it to convey signals from one part of a country to another. Iron wire is laid down between two places, and the electric signal, which is communicated at one end, is conveyed to the other in an instant of time. This contrivance is called the *Electric Telegraph*. It has also been used in blasting rocks; the powder being ignited by electricity conveyed along lines of wire, instead of being ignited by the slow and dangerous mode of burning matches.

125. The air is seldom highly overcharged throughout a great space. Hence, thunder-storms rarely spread over many miles of the sea or land. There is almost always a space of time

between our seeing the flash of the lightning and hearing the sound of the thunder. This is because sound requires some time to travel to us. It proceeds, in ordinary circumstances, at the rate of 1190 feet in a second. We may thus calculate how far any flash of lightning is distant from us, the number of seconds multiplied by 1190, or 1190 multiplied by the number of seconds, giving the distance in feet, which we may easily reduce into yards and miles. If several seconds elapse between our seeing the flash and hearing the report, we may be certain that the electric action is at such a distance as, to ourselves at least, to involve no immediate danger.

126. The atmosphere, in certain conditions, shews other wonders arising from electricity. The most remarkable of these is the *Aurora Borealis*, a bright pale light which is sometimes at night seen shooting up in streams from the northern part of the sky.

127. The nervous system of the bodies of animals is supposed to depend in some way upon electricity. In some animals, particularly in a fish called the *torpedo*, the electric power is so great, as to communicate a shock when the creature is touched. It appears, in these instances, to be designed as a means of defence against the assaults of other animals.

128. The electric principle appears to be connected, if not identified, with an affection of matter which passes by the term *magnetism*. This has been found to reside in an unusually large proportion in one of the ores of iron, called the *loadstone*, from which it can be communicated to any other piece of iron by rubbing. Metals thus possessed of the magnetic power attract other pieces of metal, and are found to have what are called *poles*—that is, two opposite points, between which the electric or magnetic influence is perpetually, though invisibly, flowing. The body of the earth seems to be itself affected in this manner, and to be, in fact, a great magnet, having its two poles near the North and South Poles. The attraction of these poles makes small magnets tend to arrange themselves in the same direction; and this is a circumstance highly important to man, who, by poising a magnetised needle upon a central pivot, is enabled, by its always pointing north and south, to know, in any part of the world, by sea or land, the direction in which he is going. A needle properly fitted up for this purpose constitutes the instrument known by the name of the *mariner's compass*.

129. The phenomena of electricity may be produced either by *friction* (ordinary electricity); by *magnets* (electro-magnetism); by *heat* (thermo-electricity); or by *chemical action* among certain substances (Galvanism, from the name of

Galvani, an Italian philosopher). So many discoveries have been made under each of these heads, and such a variety of instruments and apparatus invented to exhibit the phenomena, that each may be considered as a separate department of science. Subtle as electricity and magnetism seem, man has been able to employ their agency to useful purposes. Besides the mariner's compass, which depends on magnetic influence, he has been able to decompose the hardest metals by the power of electricity; he employs the electric shock in cases of disease, by the rapidity with which electricity is conducted along metallic substances; he has employed it in conveying signals from one part of a country to another; and by collecting it in great force from galvanic troughs and magnetic coils, he has applied it as a moving power to machinery.

VITREOUS—from the Latin *vitrum*, glass—produced by, or partaking of the nature of, glass.

RESINOUS—produced by, or partaking of the nature of, resin or wax.

EQUILIBRIUM—from the Latin *equus*, equal, and *libra*, a weight or balance; anything held in equal balance or counterpoise is said to be in equilibrium. Two bodies, one possessing more electricity than the other, are not in equilibrium; but when the one gives off half of its surplus, so that both have the same quantity, they are then said to be in equilibrium.

TELEGRAPH—from the Greek *tele*, far off, and *grapho*, I write. Inventions which describe occurrences at a distance are telegraphs.

LOADSTONE or LODESTONE—from the Saxon *lædan*, to lead; so called from other pieces of iron being led or attracted towards it, or from its always leading or pointing towards the North Pole.

THE ATMOSPHERE.

130. The earth is entirely surrounded by a fluid, which we usually call the *air*, but which is termed by men of science the *atmosphere*. This fluid is so thin and clear, that it appears to possess no substance whatever; yet it is as truly a substantial fluid as water. We feel its resistance when we move rapidly through it; and we experience its effects when it flows in violent currents, producing winds and tempests. It is supposed to extend no higher than forty-five miles above the earth's surface, always becoming rarer the greater the elevation. This difference in density is produced by pressure, that portion of the atmosphere near the ground being pressed down or made denser by the weight of the parts above it, just as the lower parts of a hay-stack will be rendered closer and denser by the pressure of the parts above.

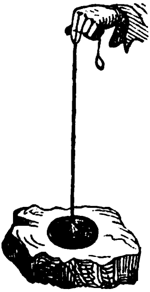
131. The atmosphere, as found near the earth's surface, is composed of various gases, in the proportion of one part of the

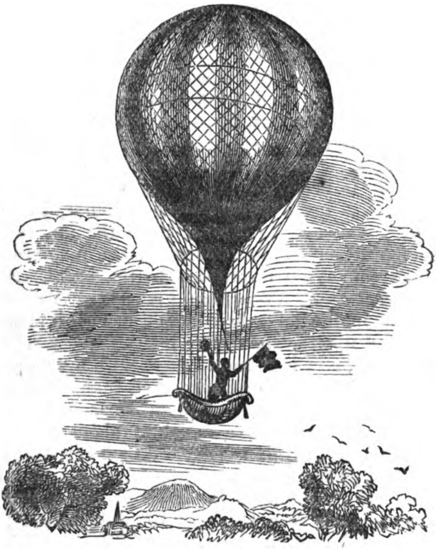
gas called *oxygen* to four of *nitrogen*, along with a very small portion of *carbonic acid gas*. Thus composed, but in no other proportions, it is fitted for sustaining animals, by being inhaled into their lungs; and vegetables, by being absorbed through small pores. It is chiefly the part called oxygen which is used by animals in breathing. Oxygen, entering by the mouth into the lungs, communicates a quality to the blood, without which life soon ceases. Uniting chemically with the carbon in the blood, carbonic acid gas is formed, and thrown back with our expired breath. The heat of our bodies is generally understood to arise from this chemical process. If we continue to breathe in a small and confined place, we in no long time exhaust the air of its more useful ingredient, and overcharge it with carbonic acid gas, which is unfavourable to life and health. This is the reason why it is not proper to keep our rooms constantly close: all rooms, churches, and other such places, where people meet in small or large numbers, ought to be frequently opened to admit fresh air. It might be supposed that the breathing of so many animals would soon render the whole atmosphere unhealthy; but, by a wonderful provision, vegetables retain chiefly those parts which animals refuse, and by the action of the sun's light, exhale or give out the oxygen, so that a constant balance is preserved, and the air is kept from age to age in one constant state of freshness.

132. The air is necessary for several other purposes. The world would, for instance, be without sound, for sound is produced by percussions or strokes upon the air, throwing it into a peculiar agitation, so as to affect the membrane of the ear, and thus convey an impression to the brain. Air, being a substance, necessarily possesses gravity or weight. One hundred cubic inches have been found to weigh about thirty-one grains; and upon every square inch of every substance on earth, the whole mass is found to press with a weight equal to fifteen pounds. Thus, an ordinary sized man, with a body of about two thousand square inches of surface, is pressed on every side by an atmosphere equal to about fourteen tons, which is the weight of fully twenty ordinary cart-loads. Now, it happens, that, so far from this being burdensome, it is agreeable and necessary, for, owing to the air contained in them, the juices of the body have a tendency to swell, which this pressure is exactly sufficient to counteract. Were we in any place from which the air was withdrawn, we should immediately expand in every vein, till our body would fly into pieces.

133. There are many familiar examples of this pressure around us. One of the most common consists in causing a

thimble to adhere to the hand by sucking the air from beneath it; the adhesion is the result of the pressure of the atmosphere on the exhausted space on the hand. Another consists in lifting a stone by means of a sucker, formed of a string and a wetted piece of leather, as in the accompanying figure. The wetted leather is in this case pressed down upon the stone, and the string is then pulled; if the air were admitted under the end of the string, the sucker would come off; but none being admitted, a rigid pressure to the stone is produced, and the stone, if not too heavy, is lifted. Any boy will readily understand, that if the atmosphere press with a weight equal to 15 lbs. upon every square inch, a square inch of leather will be pressed both upon





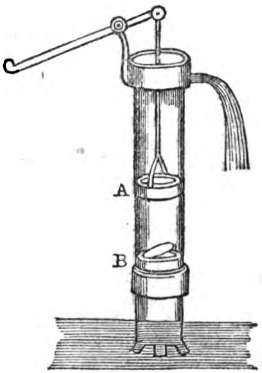
Balloon.

the upper and under surface by the same weight. But if the atmosphere be excluded from the under surface, as in the case

of the sucker, then it must press upon the stone instead; and hence the stone and sucker will be kept together by a pressure equal to 15 lbs.

134. As any substance which is lighter than the same bulk of water will rise through that fluid to the surface, and there float, so any substance lighter than the same bulk of air rises through the atmosphere, until it attains a height where the weight of both is equal. Thus, if we fill a thin silken bag with the gas called *hydrogen*, which is much lighter than common air, it will ascend into the air, provided that the bag and the hydrogen together do not weigh more than the quantity of common air which the bag displaces. This principle has been taken advantage of for the construction of what are called *balloons*—namely, large bags of hydrogen or of common gas, with a car attached below, in which one or more persons can ascend many thousand feet above the surface of the ground, and, driven by the wind, travel to a great distance with extraordinary rapidity. All that is necessary is, that the machine, and the substances connected with it, including the travellers and the contained gas, should not be heavier than the quantity of common air which would in natural circumstances occupy their place.

135. Water is a denser fluid than air; and hence a column of water, 32 feet in height, has been found to weigh the same as an equal column of the whole atmosphere, which is 45 miles in height. A knowledge of this fact has led to many important contrivances; one of the most familiar of which is the raising of water by means of the pump, which can only be done when the lower valve (B) is not more than 32 feet above the surface of the water.* One of the metals, mercury or quicksilver, which in ordinary temperatures is fluid, is much denser than water; and hence a column of it, only 30 inches in height, is of the same weight as an equal column of the whole atmosphere. Observing this fact, and further perceiving that the weight of the atmosphere generally became less on the approach of rainy weather and



* The action of the pump may be here explained.

storms, men of science have formed an instrument called the *barometer*, in which the rising and falling of a column of this metal contained in a glass-tube, as the atmosphere chances to become lighter or heavier, betokens the condition of the air for a great distance around, and foretells what will be the nature of the weather for some time to come.

136. It is only within one or two miles above the level of the sea that the chief beneficial uses of the atmosphere are experienced. It is there of sufficient density to sustain animal life with comfort, to communicate sound, and to aid in the diffusion of heat. Near the level of the sea, water boils under a heat indicated by 212 degrees of Fahrenheit's thermometer; but at the top of Mont Blanc, a mountain nearly three miles high, the same fluid boils at 189, or 23 degrees of less heat. This phenomenon is produced by the greater weight which the atmosphere exerts on the surface of the water near the sea, than at great elevations.

BAROMETER—*baros*, heavy, and *metron*, a measure—an instrument devised for ascertaining or measuring the weight of the atmosphere.

WINDS.

137. Wind is the air in a state of motion. By waving the hand rapidly, or blowing our breath strongly, we may form a movement or agitation of the air on a small scale. Winds in nature originate from a variety of causes. When the air at any particular place becomes heated or rarefied, it ascends because of its greater lightness, leaving a vacancy which the colder air of neighbouring regions rushes in to supply. This is considered as one of the chief causes of winds. An exactly similar process may be observed going on, if we throw open the door of a room in which there has for some time been a good fire. If we hold a lighted candle near the top of the open doorway, the flame will be blown outwards; if near the bottom, inwards. In the one case, the flame is blown by the heated air going out, and in the other, by the cold air coming in to supply its place. The great and continual heating of the air in particular parts of the tropical regions by the sun, and its consequent rising into higher altitudes, cause a constant rushing of air from all neighbouring parts towards those places. Hence, in that part of the earth, there are winds which blow for months at a time from east to west: they are called *trade-winds*, because mariners who have occasion to sail on the Atlantic and Pacific Oceans take advantage of them in

their voyages. The winds are of use in dispersing the clouds over the surface of the earth; in purifying the atmosphere from noxious vapours and effluvia; in dispersing the seeds of plants; in impelling vessels over the surface of the sea; and in moving various sorts of machinery.

138. Besides the trade-winds, there are several others of a peculiar and interesting character. These are the *monsoons*, which are merely the trade-winds turned to the south or north by portions of the land lying within the tropics; the *simoom*, a burning pestilential blast, which rushes with fury over the sandy deserts of Arabia; the *harmattan*, a cold dry wind, which is frequent in Africa and eastern countries; the *sirocco*, a hot, moist, and relaxing wind, which visits Italy from the opposite shores of the Mediterranean; the *bize*, a cold frosty wind, which descends from snow-covered mountains like the Alps; and *whirlwinds* or *tornados*, which are common to all countries, but most destructive in warm regions.

VAPOURS—CLOUDS—RAIN.

139. From the surface of seas, lakes, pools, and from all bodies containing moisture, more or less water is always rising in the form of *vapour*. This process is called *evaporation*. The vapour of water is quite clear and invisible, like air. When a little water is spilt on a table, it soon disappears, and yet we see nothing rising up. If, however, we hold a wet towel near a fire, we do see a cloud or fog rising from it. The reason of this is, that the vapour rises very rapidly from the hot towel, and, mixing with air colder than itself, a portion of it is changed back into water; and it is the minute specks of water floating in the air that form the visible cloud or smoke. Although, then, we are in the habit, in ordinary language, of calling clouds and mists, and the watery smoke that we see issuing from a boiling kettle, vapour, these are, strictly speaking, not vapour, but vapour converted back again, or *condensed*, as it is called, into minute particles of water. It is important to keep this in mind in speaking of the formation of clouds and rain.

140. It depends upon the degree of heat how much vapour can rise and remain in the air in an invisible state. When the temperature of a room is at 60°, and a surface of water is exposed in it, evaporation goes on to a certain extent; but if the air is prevented from changing, it soon comes to a stand; the air can hold no more, and is said to be *saturated*. But if the temperature is now raised to 80°, the evaporation will go on again, until the quantity of vapour in the room is about doubled, when it will

again stop. Suppose, next, that the room is allowed to cool from 80° to 60°, the air at the lower temperature can no longer hold so much vapour, and about the half of what was in it is condensed into water, and forms dew or damp upon the walls; or, if the cooling was sudden, appears as a fog in the air of the room. Although, for the sake of convenience, we speak of the air containing the vapour, it is rather the space that contains it; for if the room were a vacuum or space empty of air, the same quantity of vapour, and neither more nor less, would rise into it as before, according to the temperature.

141. These facts about the nature of vapour enable us readily to understand how clouds are formed. When a portion of air remains for some time over water, or over land containing moisture, it soon becomes saturated, or nearly so, with vapour; and then no sooner does anything occur to cool it, than part of its invisible vapour is changed into visible vapour, which is water in the form of dust, as it were, floating in the air and forming clouds. There are many ways in which a stratum of air is liable to be cooled. One of the most common causes is, that those portions of air that happen to be more heated than the rest, are always ascending; and when air ascends, it becomes rarer, and this always causes its temperature to fall. When a current of warm moist air, again, is flowing over the earth's surface, and comes to a mountain, it must ascend to get over it; and in ascending, it becomes rare and cold, and must part with its moisture. This is the reason why a cloud is frequently seen on a mountain-top, when the air around is clear.

142. Although we can thus explain the circumstances under which clouds are formed, there is a difficulty in understanding how the minute particles of water of which they are composed are upheld so long in the air as we often see them, without any tendency apparently to descend. It is only, as would appear, when some unknown cause brings several of the particles together so as to form drops of some size, that they begin to fall; and then, in their descent, they meet more and more particles, and thus become larger as they approach the ground. Every cloud does not necessarily descend in rain; if it happens to be made warmer, either by the sun, or by a current of dry, warm air mixing with it, the watery particles are again dissolved into invisible vapour. The deposition of dew on plants and other objects on clear nights, when there is no appearance of rain or fog, is accounted for in this way: As soon as the sun goes down, the solid objects on the earth's surface begin to throw off their heat by radiation, and soon become colder than the air, which loses but little heat in this way. It is the tips of grass, the hairs of leaves, and such like small pointed objects, that become soonest

cold by radiation; and on a calm night, when the same film of air remains some time in contact with these cold objects, it too becomes chilled, and part of the vapour in it is condensed into specks of water, which adhere to the objects, and grow into drops of dew.

143. Clouds have two distinct uses: first, they serve the purpose of shade against the sun's rays, and so prevent his heat from scorching up the produce of the earth; and, second, they act as reservoirs of moisture to refresh the ground and strengthen vegetation. Clouds thus restore to the earth, in useful rains, the moisture which has been carried off in the process of evaporation.

144. Evaporation takes place by artificial, as well as by natural means. If heat or fire be applied to a vessel containing water, the water will gradually fly off in steam or vapour. The force with which steam flies off from boiling water is very great; and this force or power is rendered serviceable in moving that powerful machine, the steam-engine.

145. The phenomena of winds, clouds, rain, evaporation, thunder, meteors, and all other things remarkable in the atmosphere, form the subject of the science of METEOROLOGY.

METEOROLOGY—from the Greek *meteora*, a meteor, and *logos*, a discourse—the science which discourses or treats of those atmospheric phenomena called meteors. Meteors are of three sorts—1. *Luminous*, or *fiery*, such as rainbows, falling-stars, lightning, &c.; 2. *Airy*, such as winds, hurricanes, and tempests; 3. *Aqueous*, such as mists, fogs, rain, snow, water-spouts, &c.

WATER.

146. Water is one of the most abundant and generally diffused bodies in nature. Though appearing in the form of a liquid substance, it is, in reality, composed of two gases, hydrogen and oxygen, in the proportion of one part of the former to eight of the latter. Its particles or atoms are so slightly united with each other, that the whole mass *flows* easily, and adapts itself to the shape of the interior of any vessel into which it is admitted. This property belongs more or less to all fluids or liquids, and hence *they press equally in all directions*, while solids press only in one direction, or downwards. A remarkable property in water, arising from this uniformity of pressure, is its rising to the same surface-level in all parts of its volume. For example, if we fill a tea-pot with water, we shall find that the fluid has risen in the spout to precisely the same height as in the pot, and that the small column of water in the spout balances, or cannot be pushed out or over by, the volume of

water in the pot. These simple truths were not known to the ancients, who constructed long level canals, resembling rivers, for bringing supplies of water into their towns. In modern times, water is conveyed to great distances through close pipes from springs and fountains. These pipes are laid beneath the surface of the ground, along the risings and fallings of the country, yet they convey the water, without difficulty, to any height which is not above the level of the fountain whence the water has flowed. It is in this manner that most large towns are now supplied with water.

147. The easy motion of water in all its parts causes it to flow, and hence we have springs, rivers, currents, and other phenomena of running water. It also allows it to be easily agitated, and hence the waves, tides, and other agitations of the ocean. The force of running water has been of essential service to man in all ages, and is still one of the cheapest and most prevalent of moving powers applied to machinery.

148. Water buoys up any object on its surface which is lighter than itself, bulk for bulk. Any object, also, on being plunged into water, weighs lighter in the water than it would weigh in the air, because it is partially supported by the liquid on all sides. A block of stone is as much lighter under water as the weight of the water which would otherwise occupy its place amounts to; thence such blocks are much more easily moved below the surface of water than above it.

149. The branch of science that treats of the pressure of water and other liquids at rest is called Hydrostatics, while the science of water in motion is called Hydrodynamics; Hydraulics, again, has reference to the flow of water in pipes and channels. The various machines in which water is concerned are considered under these heads.

HYDROSTATICS—from the Greek *hydor*, water, and *status*, a standing—the science which relates to the pressure or weight of standing water.

HYDRODYNAMICS—*hydor*, and *dynamis*, power—the science which treats of the power or force of water.

HYDRAULICS—*hydor*, and *aulos*, a pipe or channel; hence it is the science of running water, or water moving in pipes or channels. Water-wheels, pumps, syphons, and other mechanical contrivances connected with the motion of water, are treated of under this branch.

ELEMENTS OF MATTER—THEIR COMBINATIONS.

150. The material world immediately under our observation, including such parts of the earth's crust as have been explored, the plants and animals upon the earth, and the atmosphere which envelops it, is found to consist of about sixty substances,

just as all the words which compose a language are resolvable into a few letters. These substances, having hitherto resisted all endeavours to divide or resolve them into any others, are termed the *elements of matter*, or *simple substances*. But these simple substances are rarely found by themselves in nature. They are generally combined with each other, two by two, or three or more together, and it requires some trouble to separate them. This compound state of matter shews very clearly that the world must have been created by an Intelligent Being, who designed everything with the greatest care, and fitted all things for each other. In some of the substances of the material world, old combinations are constantly in the course of being undone, and new ones made up: the rotting of one substance and the growing of another out of it, is an example; so is the nourishment of the body by food; so, also, is the change effected in our lungs upon the air which we are every moment breathing.

151. The investigation of the laws under which the simple substances have formed the numerous compound substances which we see in nature, and the means by which compound substances can be resolved into their original elements, or thrown into new combinations, are the objects of the science of CHEMISTRY, the full importance of which has only been brought to light by the discoveries and experience of recent times.

152. Five of the elementary bodies are *gases*, by which is meant, as nearly as common language can express it, fluids in the form of air. Their names are Oxygen, Hydrogen, Nitrogen, Chlorine, and Fluorine; but the first three are by many degrees the most important. It has already been mentioned that hydrogen and oxygen form water, and that nitrogen and oxygen are nearly the sole ingredients in atmospheric air.

153. A large proportion of the simple bodies are *metals*, fourteen of which have long been more or less known and used—namely, Gold, Silver, Mercury, Lead, Copper, Zinc, Iron, Tin, Bismuth, Cobalt, Nickel, Manganese, Antimony, and Arsenic. Other twenty-four are of more modern discovery, and, from their scarcity and other causes, have been applied to few important purposes. These are, Platinum, Rhodium, Palladium, Iridium, Osmium, Cadmium, Tellurium, Selenium, Chromium, Vanadium, Uranium, Molybdenum, Tungsten, Columbium, Titanium, Cerium, Lantanium, Ruthenium, Didymium, Pelopium, Niobium, Norium, Tantalum, and Terbium.

154. Twelve other metals were discovered in the present century, as the bases or fundamental constituents of substances which formerly were considered to be simple. Of the twelve, nine had appeared to be what are called *earths*, and

three what are called *alkalies*—terms to be afterwards explained. On these earths and alkalies being found to be fundamentally metals, their names were respectively conferred on the metals, with the distinction of a termination in *um*. Thus, the nine earth-composing metals were styled Aluminum, Glucinium, Yttrium, Zirconium, Thorium, Calcium, Magnesium, Barium, and Strontium; while the three alkali-composing metals were denominated Potassium, Sodium, and Lithium.

155. The remaining simple bodies found in nature are reducible under no fixed class. They are named Carbon, Boron, Phosphorus, Sulphur, Silicon, Iodine, and Bromine. These, along with the five gases, Oxygen, Hydrogen, Nitrogen, Chlorine, and Fluorine, are generally spoken of as the *non-metallic* elements, in contradistinction to the class of metals.

156. The chemical characters of the elemental substances chiefly bear reference to their combinations. Five—oxygen, hydrogen, chlorine, fluorine, and iodine—appear to have the power of combining with all others; oxygen possesses this property in a very conspicuous degree, and does in reality form a part of almost all substances found in nature. These five bodies are usually styled, from another general feature of their character, *supporters of combustion*.

157. The first step taken by nature towards the forming of other and more intricate combinations, is the union of two simple bodies. Oxygen is the great agent which joins with and prepares the other simple substances for further associations; and many of them, such as the metals, form scarcely any compounds till they have been united to oxygen—in other words, formed into an *oxide*. The rust of common iron is an example of a metallic oxide, being a compound of particles of the metal with particles of oxygen drawn from the air or from water or damp. Another metallic oxide may be easily produced by shaking quicksilver for a short time in an open phial; the dull scum-like substance which is then observed upon the surface of the fluid metal is an oxide, formed by the union of particles of the mercury with particles of oxygen drawn from the air. This compound substance, then, called oxide, is a preliminary to most other combinations. The first compounds of the gas chlorine are in like manner termed *chlorides;* common salt is chloride of sodium. The similar combinations formed by the other three supporters of combustion do not occur to any considerable extent in nature.

158. Nine of the metallic simple bodies, as already mentioned, are the bases of substances called *Earths*. It is by combination with oxygen that they form earths; and in

nature they are never found but in this combination. The names of the earths are alumina, glucina, yttria, zircon, thorina, calx (Latin for *lime*), magnesia, baryta, and strontia; from which words, as already stated, the names of the metallic bases were formed by the termination *um*. The general characters of the earths are, insolubility in water, and the power of forming salts with the acids. They are brittle, whitish, tasteless, and very little liable to be affected by heat. Four of them—magnesia, lime, baryta, and strontia—are termed Alkaline Earths, from their possessing some of the characters peculiar to the alkalies. The earths alumina and lime form a very extensive portion of the crust of the earth. The vast lime-beds, which have been described, in another part of this work, as composing so much of the Secondary Formation, are (chemically speaking) *carbonates of lime;* in ordinary language, the earth-lime, which is a compound of the simple body calcium with oxygen, is here recombined with a certain proportion of carbonic acid (acid formed by the union of the simple body carbon with oxygen), so as to compose what is called carbonate of lime. This ultimate combination falls under the class of substances chemically called *Salts.*

159. Potassium and sodium, which, like the preceding nine, are never found in nature in their simple state, constitute, in combination with oxygen, the well-known substances potash and soda, which bear, in chemical language, the appellation of *Alkalies* proper. The very rare substance *lithia*, which is a compound of the metal lithium with oxygen, is another alkali. The word alkali was originally employed by the people of Arabia to designate an Egyptian plant, the ashes of which had an acrid taste. It has since been employed to signify the three bodies above mentioned, along with a third named *Ammonia*, which is a gas compounded of hydrogen and nitrogen, extracted from soot and decayed animal matter. The first two alkalies abound in the mineral and vegetable kingdoms. They have a powerful effect in washing clothes, from their readiness in uniting with any unctuous matter; but for this purpose, soap, which is a compound of soda and tallow, is now more generally used. The alkali, ammonia, being an impalpable gas, requires to be mixed with water in order to be used. It then becomes the well-known scent called hartshorn. In its gaseous state, it is familiar to our sense of smell, being the predominant odour in newly cleaned stables. The principal properties of the alkalies proper are, solubility in water, the power of changing vegetable blue to green, and the power of uniting with acids and *neutralising* them, that is, causing their acid properties to disappear.

160. The metals, potassium and sodium, have the strongest attraction or affinity for oxygen of any of the elements. If a piece of potassium be dropped upon water, it instantly ignites, and burns with a brilliant flame. This is caused by the rapid absorption of oxygen from the water, which oxidises the potassium, and forms potash.

161. It has now been seen, that, of the primary combinations, some are formed by the union of oxygen with certain metals, and termed *oxides;* others by the union of oxygen with certain other metals, and termed *earths;* and three others also by the union of oxygen with metals, and termed *alkalies.* All these compounds go by the general name of *bases* or basic substances, because by uniting with acids they become the bases or chief ingredients of salts.

162. *Acids* form a very important class of substances in chemistry. They are mostly distinguished by their sour taste, and hence their name. They have also the power of changing vegetable blues into red; and when an acid is mixed with an alkali, they neutralise one another; that is, the distinguishing qualities of both disappear, and a compound called a salt is formed, having properties different from either. Acids are all compound substances, and oxygen is generally, though not always, one of the ingredients. Oxygen was at one time considered to be the only acidifying or acid-producing principle, and hence its name. But it is now known that some of the most powerful acids have no oxygen in their composition. Thus, hydro-chloric acid (formerly called muriatic acid) is composed of hydrogen and chlorine alone; nay, according to the now prevalent view, the acids into which oxygen enters really owe their acid character to the hydrogen of the water, which is always an ingredient in their composition. Be this as it may, oxygen plays a prominent part in most acids, as it does in most bases. But it is to be remarked that when oxygen unites with any other element to form both a base and an acid, there is always a greater proportion of oxygen in the acid than in the base. Thus, oxygen unites with the metal manganese in a certain fixed proportion to form oxide of manganese, which is a powerful base, and neutralises acids. But the combination of oxygen with manganese also forms an acid, called manganic acid, and in this compound the proportion of oxygen is three times as great as it is in the oxide. Oxygen often forms more than one acid with the same element, by combining with it in different proportions. Thus, with sulphur it forms two acids, one in which there are two atoms of oxygen to one of sulphur, and another in which there are three. The acid with the higher proportion of oxygen is called sulphur*ic* acid; the other,

sulphur*ous* acid; and this principle of naming is observed in other acids. The salts formed with the sulphuric acid are termed sulphates; and those of the other, sulphites; which terminations distinguish other salts in similar cases. A few of the principal substances of this class are, the sulphuric, sulphurous, nitric, nitrous, hydro-chloric, iodic, boracic, acetic, tartaric, oxalic, citric, and benzoic acids. The last five of these acids are called vegetable, and are more complex in their composition.

163. The *Salts*, arising from the combination in definite proportions of acids with alkalies, earths, and other metallic oxides, are very numerous, and are found everywhere in nature. In a state of solution, they constitute a great portion of the weight or bulk of the ocean; incorporated with minerals, or in a pure state, they form no mean part of the earth's crust; and in a condition which is not perfectly understood, they exist in abundance in the vegetable world. A salt, as we have said, is formed by the union of an acid with a base, and we might expect that all the ingredients of both acid and base would be found in the salt; but this is not the case. Thus, when hydro-chloric acid, consisting of hydrogen and chlorine, unites with soda, consisting of sodium and oxygen, the result is the well-known substance, common salt. But this salt contains only sodium and chlorine; while the oxygen of the soda and the hydrogen of the acid combine, and form water. In general, the oxygen of the base combines with the hydrogen of the acid to form water, and the other elements go to form the salt. It is impossible in this place to give any account of individual salts, but the principal are formed by those acids enumerated. Both the acid and the base are indicated in the name of the salt; as sulphate of soda, tartrate of potass.

164. The combination of bodies takes place under certain laws. The leading law is generally expressed by saying, that when two substances unite to form a third substance, each ingredient has always a certain definite and unchangeable proportion to the other; or more shortly, *combination always takes place in certain fixed and definite proportions*. Thus, water, as we have said, is a compound of oxygen and hydrogen; but it is not a varying compound, like one of water and sugar, which we may mix in any proportion, from a slightly sweetened water up to a sirup. We do not find that some waters are stronger, so to speak, in oxygen than others; for when water is analysed, or separated into its two ingredients, no matter from what part of the earth or air the water was taken, there is always found to be one proportion by weight of hydrogen for eight of oxygen: that is, if nine grains of

water are analysed, there will be eight grains of oxygen, and one grain of hydrogen. The same truth is confirmed by bringing oxygen and hydrogen together and making them combine. This is done by mixing them in a jar and applying a flame; the two gases unite with a flash, and water is left in their stead. Now, if there are eight grains of oxygen put into the jar, and one of hydrogen, the whole of both gases will disappear, leaving nine grains of water; but if there are, say, eleven grains of oxygen, and one grain, as before, of hydrogen, then, after the flash, there will be found in the vessel just nine grains of water, as before, together with three grains of oxygen, left uncombined.

165. But although oxygen and hydrogen are combined in the unvarying proportion of eight to one in water, they do combine in another proportion than this; but then it is to form an altogether distinct substance from water. By an artificial process, chemists produce, from the union of oxygen and hydrogen, a colourless, sirupy liquid, of a peculiar nauseous, bitter, and astringent taste, which is called deutoxide of hydrogen. Now, the proportions of the two ingredients in this compound are sixteen of oxygen to one of hydrogen—that is, the proportion of the oxygen is twice as great as it is in water. The same principle is found to hold good in all similar cases, and forms another important law of combination—namely, that when two substances unite to form several distinct compounds, the proportion of the varying ingredient in the several compounds differs by being twice as great, or three times as great, and not in any intermediate degree.

166. These facts regarding the combinations of the elements in compound bodies are explained by a theory first propounded by Mr Dalton of Manchester, and called the *Atomic Theory*. Any piece of matter, it is well known, can be broken into small pieces, and these again into still finer and finer particles, as long as we can see them. Notwithstanding this, there is good reason, it is thought, for believing, that far beyond the limits of our senses, there are final particles or *atoms*, incapable of being any further divided. The atoms of the different elementary bodies are conceived to have different properties and different weights—an atom of oxygen, for instance, weighing eight times as much as one of hydrogen. The different kinds of atoms have attractions or affinities for one another, some weaker and some stronger. These affinities lead them to unite, and when they do so, they go together in pairs. Thus, when oxygen and hydrogen are brought together, their atoms pair off, one of oxygen with one of hydrogen, each pair forming a compound particle, with different

properties from either of its elements, and a collection of them making the new substance water. There are thus the same number of atoms of hydrogen in water that there are of oxygen; but as the atoms of oxygen are eight times as heavy as those of hydrogen, the proportion of hydrogen by weight in any portion of water is only an eighth part of that of oxygen. In forming the deutoxide of hydrogen, again, two atoms of oxygen combine with one atom of hydrogen, thus forming a triple particle.

167. Two bodies, uniting together, produce almost always a compound, with properties and a form differing from that of either ingredient. Thus, water results from the combination of two gases. When two or more compounds are formed by the same ingredients, but in different proportions, these compounds may possess the most opposite properties. Thus, the two gases, oxygen and nitrogen, enter into five combinations with each other, producing nitric acid, nitrous acid, nitric oxide, nitrous oxide, and common air. The first three are virulently poisonous, and the last, strange to say, is the breath of man's life. The assumption of a solid form by a gas, or the conversion of a solid into a gas, by combination with other bodies, and the total change of properties consequent upon such changes, are facts easily demonstrable, and tend to lessen our wonder at the immense variety of objects in nature, arising from a few fundamental constituents.

168. Whether in the great laboratory of nature, or in the workshop of the chemist, two of the chief agents by which the forms of bodies are changed, and existing combinations broken up, or new ones formed, are *Fluidity* and *Heat*. When two substances are mixed together in a perfectly dry state, no action or union takes place between them, except in a few rare instances; in general, before a union can be effected, they require to be dissolved in a fluid medium, such as water. The water has an equal attraction over its whole bulk for the substance placed in it, and thus divides it into its constituent particles, which then act readily on the atoms of other bodies brought into contact with them. Substances are said to be *soluble* when water has this attraction for them; and to what extent matter is divided by solution, is shewn by the fact that the ten-millionth particle of a grain can be proved by experiment to exist in a drop of water. Heat, it is well known, expands bodies; and if applied with sufficient force, it changes solids into liquids—that is, *fuses* them, and converts liquids into vapour. The latter process is that formerly described under the term *Evaporation*. To the chemist, the process of evaporation is of great utility, for, by exposing the water

which holds any body in solution to the action of heat, the water flies off in vapour, leaving the dissolved substance at the bottom of the vessel employed. From the finely divided state in which a body exists in solution, it might be supposed that the substance thus procured by evaporation would be in the state of a fine powder. This is often not the case; *Crystals* of the substance are formed, and, what is more remarkable, the crystals of one body are always of the same form and appearance. Crystallisation is one of the most interesting of chemical operations. It is seen extensively in the flakes of snow which fall from the air, and in the beautiful flowery figures which overspread our windows after a frosty night. Salt and sugar are also familiar objects of this kind. A fine specimen of crystallisation may be thus produced: Take a wide-mouthed phial, into which put a drachm of sugar-of-lead; fill up the phial with water, and shake it to dissolve the powder. From the cork of the phial suspend a small piece of zinc by a thread, so that it may dip into the mixture. In the course of a few hours, the zinc will be found to have attracted the whole of the lead, which will be found hanging by it in the form of an inverted tree, of a very beautiful appearance.

169. Evaporation, crystallisation, and solution, are, however, in some measure, merely modes by which chemical phenomena are exhibited; the great fundamental cause of all the changes of form which bodies undergo, and of the combinations they enter into, is the power of attraction. By this power, which, as manifested between the atoms of different substances, chemists call *Affinity*, the particles of a solid or a fluid adhere to each other, and by the same their cohesion is destroyed. Every body possesses an affinity for other bodies in a greater or less degree, and in proportion to that degree, will its tendency to unite with them be strong or otherwise. When the affinity between two substances is great, they will even break up connections with other bodies, in order to unite with one another. An example may be thus exhibited: Let a solution of tartaric acid and a solution of carbonate of soda be mixed together, and an effervescence immediately ensues. The carbonate of soda is a compound of carbonic acid and soda, which have an affinity for each other; but between the tartaric acid and the soda a still stronger affinity exists; and when the solutions are mixed, the carbonic acid gas is dislodged, and the tartaric acid combines with the soda in its place, forming what is called a tartrate of soda. A series of changes of this kind can easily be produced. Thus, sulphuric acid readily combines with ammonia; if a little lime be added, the sulphuric acid

leaves the ammonia, and flies to the lime; add soda, and it leaves the lime; potass, and it leaves the soda; strontia, and it leaves the potass; and finally, if the earth baryta be added, it will leave the strontia, and remain in conjunction with the baryta. If two or three compound substances of different properties be added, a scene of confusion at first takes place; but ultimately the ingredients will be found to have united with each other, each remaining in union with that for which it has the strongest affinity. A knowledge of these varying affinities is the means by which the most of the substances found in nature are made available to human use.

170. This is an exceedingly superficial view of the principles and phenomena of CHEMISTRY. A more minute knowledge of this important science opens up an enlarged view of the great operations of nature, as well as divers useful processes in the arts. It is by chemical action, in connection with heat, light, air, and moisture, that seeds germinate in the soil, that plants grow, and that flowers are decked with various colours and tints. Hence, a knowledge of the principles of chemistry, which regulate these operations, is of the utmost value to the gardener and farmer. It is by chemical action that the food received into the stomachs of animals is transformed into blood, bone, muscle, fat, hair, and other kinds of animal structure; and a knowledge of these operations is calculated to be beneficial in the regulation of diet, with the view of keeping the body in a state of health. It is by chemistry that man has been able to extract from minerals and vegetables those valuable substances used in medicine. It is likewise by chemical action that vegetable and mineral dyes are prepared, and their colours fixed in woollen, linen, and other kinds of cloth; and it is by the same action that all bleaching and scouring operations are performed. Chemical knowledge assists in extracting the metals from their crude ores, and in compounding and preparing them for the purposes of life. The extraction of carburetted hydrogen gas from coal, for the purpose of lighting streets, houses, and shops, is one of the triumphs of chemistry; and all the arts of life, such as brewing, baking, tanning, dyeing, and bleaching, have been improved by its discoveries.

OXYGEN—from the Greek *oxys*, sour or sharp, and *geno*, I form; so called from its property of forming acids when it unites with certain substances.

HYDROGEN—from *hydor*, water, and *geno;* so called from its possessing the property of forming water when in union with oxygen. Many of the simple substances have likewise obtained their name from some peculiar property which they possess.

ATOM—from the Greek, *a*, not, and *temno*, I cut; that is, what cannot be cut down or divided into smaller portions. The ultimate particles of matter are therefore called atoms, and it is the union of the atoms of any two bodies which forms a chemical union. Atoms of oxygen uniting with atoms of iron, form rust or oxide of iron, which is at first an almost imperceptible film on the surface of the iron, because only one film of atoms can come in contact with the oxygen of the air; but as film after film is oxidised, the rust becomes thicker, and forms a crust of a reddish colour, very different in character from either the oxygen or the iron. By expelling the oxygen from rust, it can be reconverted into metallic iron.

CHEMISTRY—is supposed to be derived from *Chemi*, the ancient name of Egypt, in which country a certain amount of knowledge of this kind seems to have been early attained.

AFFINITY—from a Latin word signifying relationship by marriage; the property or tendency in two atoms to select and combine with each other.

THE VEGETABLE CREATION.

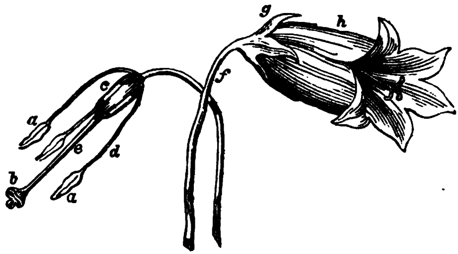
171. Matter, composed, as we have just seen, of over sixty elementary substances, may be either organic or inorganic. Plants and animals are called *organic*, because they possess a certain regular arrangement of parts or organs, which are designed to perform certain functions: they possess an active principle called life, are supported by nutriment, and exist in generations. Minerals, water, and air, are, on the contrary, *inorganic*, for they have no peculiar structure for the performance of functions. The inorganic world comprehends all the elementary substances; but only a few of these have been employed in forming the organic world.

172. Plants are a department of the organic world possessing structure and functions, with life, and supported by nutriment, but wanting several of the properties of animals. They serve many important purposes in nature, particularly that of supplying food to animals. In this respect they may be considered as a grand step in the economy of nature. Inorganic substances and fluids, in themselves useless, are thrown into the form of vegetables. Vegetables either directly support man himself, or sustain certain animals, whose flesh he eats, and which he turns to many other uses.

173. Plants require particular soils, and a certain amount of heat, to enable them to grow. Upwards of eighty thousand different kinds have been ascertained to exist. The principal varieties in their size and figure are observable by all who look over the surface of the soil, without any aid from science. We can thus class in our own minds the *moss*, growing upon rocks, or the roof of some old cottage—the *heath* blooming upon

the moorland, and the grass overspreading the meadow—the *flower* adorning the field or garden—the *grain* loaded with the food of man—the *shrub* luxuriating in the pleasure-ground—and finally, all the varieties of *trees*, from the slender birch up to the stately elm and oak. But in a department of nature embracing so many various objects, it has been found necessary to adopt a more particular classification.

174. One of the peculiarities of vegetables is, that they reproduce each other by means of seeds. Now, it was observed by a great Swedish naturalist, named Linnæus, that varieties existed in the organs or parts by which plants reproduced their own kind. He therefore originated a mode of classifying them with a regard to these varieties. One part of the apparatus by which plants reproduce each other is termed the *pistil*, marked with the letters *eb* in the accompanying picture

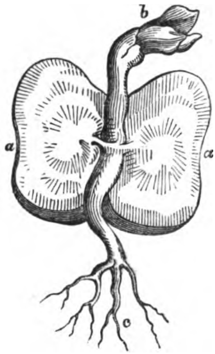


of a common flower. Another part is called the *stamen*, of which two are marked in the picture by the letter *a*. Now, some plants have one stamen, some two, and some a considerable number; some have the stamens in one part of the plant, and some in another; some have them in different flowers from the pistil, and some on the same; while a certain kind, including mosses and sea-weeds, do not shew any. Out of these various peculiarities, expressed in the Greek language, Linnæus formed the designations of twenty-four Classes of plants—as *Monandria*, having one stamen; *Diandria*, having two stamens; *Gynandria*, having stamens and pistils united; *Cryptogamia*, having no appearance of reproductive apparatus; and so on. Each of these *classes* he divided into various *orders*, with a regard to certain minor peculiarities of the same kind; each of these *orders*, again, he divided into *genera*, with a regard chiefly to peculiarities in the flower; the *genera* were finally divided into *species*, each of which was a particular plant, bearing one constant character. By means of this

classification, a naturalist is never at a loss in giving a brief and significant account of any plant that may be presented to his notice. There is another kind of classification, called the Natural System, the invention of a late French naturalist, named Jussieu. It professes to arrange plants according to the greatest number of peculiarities which they have in common. The first division by this system is into Families, according to the forms of the flowers—as *Labiate*, in which the flowers are like the lips of an open mouth (mint and dead-nettle are of this kind); *Cruciform*, in which the flowers consist of four leaves in the form of a cross (of which cabbage, turnips, and wall-flower are examples); *Papilionaceous*, in which the flower is somewhat like a butterfly (pease, beans, and broom are of this kind); and *Umbellate*, which have a head or umbel of florets, as the hemlock, parsley; and so on.

175. At the bottom of the pistil is placed a cell, usually of an oval shape, called the seed-organ or *ovarium*, on account of its containing the seeds; in the foregoing engraving, it is marked by the letter *c*. To these seeds, a germinating power is communicated, through the pistil, by a species of dust called *pollen*, which is produced and shed by the stamens. In the plants which have stamens and pistils on the same flower, the pollen is easily shed from the one part to the other, the stamens being, for this purpose, below the pistil in drooping flowers, like that represented in p. 73, and above it in upright flowers, so that the pollen may fall upon the place where it is to perform the office assigned to it. Where some flowers on one plant have stamens, and others pistils, the communication of pollen from the one to the other is not so certain to take place, yet rarely fails. There is greater difficulty when the stamens and pistils are on distinct plants, for these may be at a considerable distance from each other. Nature, however, has made wonderful provision for overcoming this difficulty. The pollen is so light, that the wind readily carries it from flower to flower. In grasses, this is generally the mode of fructification. It has also been provided that the flowers give out a sweet liquor, of which bees are fond. The bee, entering to sip this liquor, is dusted with some of the pollen from the stamens, which it carries to a plant that has only pistils, and thus works out the end which nature has in view. When the seeds in the ovarium have received the germinating power, they advance to maturity, and usually burst the cell in which they are contained. When deposited in the ground, the seed will, in proper circumstances as to air, moisture, and heat, proceed to *spring*. After it has swelled a little, the part commonly called the *eye* of the seed is broken, and a fibre is

sent forth at the opening. This quickly divides into two, one of which descends in order to become the root, *c*, while the other, *b*, ascends in order to become the stem of the plant: the



seed, *a* (here cut into two lobes or *cotyledons*), after it has for some little time given sustenance to the fibre, gradually decays. The root serves two purposes—to fix the plant in its position, and to draw up sustenance from the soil, the latter duty being performed more immediately by small spongy excrescences branching from the more solid parts of the root, and which are renewed every year. The seeds of various kinds of plants require different spaces of time for germination: the mustard-seed springs in a day; the seed of the rose requires two years.

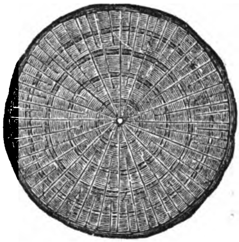
176. The most common kinds of plants are so familiar to the eye, in all their various parts and aspects, that a minute description of them is not necessary. In the engraving of a bulbous butter-cup (see page 76), *a* is the root; *b*, the bulb; *c*, *c* are the root-leaves; *d* is the stem; *e*, the stem-leaves; *f*, the branches; *g*, the flower-stalk; and *h*, the flower. Such are the most of the external parts of a plant which strike the eye of a casual observer. But in flowers, there are some minute divisions or parts, which must also be noticed. In the engraving upon page 73, the stamen, *a*, is supported by what is called a *filament*, marked *d*; *f* is the *peduncle;* while the flower is divided into two portions, the *calix* or *cup*, marked *g*, and the *corolla*, marked *h*. It is the characteristic of a shrub, that the branches issue directly out of the root. Trees, on the other hand, have roots, trunks, branches, and leaves, the branches springing out of the stem, usually at a considerable height

above the ground. The stems and branches of trees attain a woody consistency, which fits them for being used as timber.

The stalks of corn and reeds are also serviceable to man; but the stems of the most of the lesser plants are of no use, except to return in a decayed state to the soil.

177. Vegetables derive their support in nearly the same manner as animals—from food and air. From the soil, the spongy ends of the roots take in moisture, containing not only pure water, but also carbonic acid, ammonia, and certain salts. A vast number of invisible upright hollow tubes, which pervade the stem and branches, then conduct the moisture, or, as it is more usually called, *sap*, through the body of the plant or tree, till it arrives at the leaves. In daylight, about two-thirds of the oxygen and hydrogen contained in the sap flies off in vapour through multitudes of invisible pores spread over the upper sides of the leaves. The quantity of moisture thus sent forth by plants is surprisingly great; a common sunflower has been found to exhale thirty ounces in a single day. Similar pores in the under sides are at

the same time engaged in inhaling the carbonic acid gas and ammonia, which form a small part of the atmosphere, and are receiving constant accessions from the lungs of animals and from decaying organic substances. The sap, thus relieved of so large a portion of the oxygen and hydrogen, and charged with carbonic acid gas, and other substances imbibed, returns, in most plants, along the *exterior* of the branches and stem, immediately under the bark or skin, where it deposits itself in new vegetable matter, so as to add to their thickness. [The accompanying engraving represents a stem of five years old, cut across, having the *pith* (a kind of soft matter) in the centre, and a layer of timber for every year of the growth, spreading in circles towards the outside, which is covered with bark.] In some plants, of which the onion, lily, tulip, and palm-tree are instances, the sap returns along the *interior*, and the increase of substance of course takes place within. In plants of this kind, the seed invariably consists of only one lobe, whence they are called *monocotyledons;* while, in the other, it consists of two, for which reason these are called *dicotyledons.* The process of sap-nourishment only continues during the milder season of the year; at the approach of winter, the rising and falling of the sap ceases, and the leaves (except in the case of evergreens), no longer of any service, wither and drop off. When spring returns, new leaves burst from the branches, and the process of sap-nourishment is recommenced.



178. Light is essential to perfect vegetation. In the night-time, or when planted in a dark place, plants do not give out the hydrogen and oxygen of the ascending sap; on the contrary, they take in oxygen, and give out carbonic acid gas. Hence, to deprive plants of the light for any length of time, renders them unhealthy. It is the carbon that, mingling its dark hues with the yellow of the sap, forms the green colour so prevalent in the vegetable creation, and so refreshing to the eyes of man. In the absence of light, and where plants consequently do not retain carbon, they do not acquire this green colour, but exhibit a degree of paleness, which is not unjustly supposed to be a token of want of health. The exhalation of carbonic acid gas renders it dangerous to sleep in a room where there are many plants, this gas being as destructive to animal as it is favourable to vegetable life.

179. The vegetable substances which serve most directly our wants, may be classed under the various heads of Grains, Grasses, Esculent Roots, Plants strictly so called, Fruit-trees, and Timber-trees.

180. Of *Grains* (or, as they are called in science, the Cerealia, or Cereal plants), the chief are wheat, barley, oats, maize or Indian corn, rye, rice, and millet. Several of them are reared in great quantities in most countries: in 1828, twelve millions of quarters of wheat were calculated to have been raised in England alone. It is remarkable that none of the grains are anywhere found growing in a wild state; the time when they were first cultivated by man, and the means by which he obtained them, are unknown. The seeds, growing abundantly at the top of the stalk, are the parts chiefly serviceable to man. These, being ground into flour, form bread; or, by a process termed fermentation, they can be made to produce various beverages, such as beer, ale, whisky, &c. Beans, pease, and vetch, are called *Leguminous*, or pulse crops, and are also extensively cultivated as articles of food.

181. The *Grasses* are exceedingly numerous, but the most valuable are those cultivated by the farmer for pasture or for hay. Common pasture is not formed by grasses, strictly so called, but by a sward of herbs and grasses of various kinds. Rye-grass, clover, sainfoin, lucerne, and other plants of a similar description, are those generally cultivated in Britain, and are termed *artificial* grasses, in contradistinction to natural pasture and meadow hay. The straw of the cereal and leguminous crops is also largely used as fodder for horses and cattle.

182. Of *Esculents*, the potato, turnip, cabbage, carrot, beet-root, parsnip, onion, garlic, arrow-root, and cassava, are the chief, all except the last two being common to most temperate countries. The potato originally grew in Chili, in South America, whence it was imported into Britain and Ireland at the close of the sixteenth century, and afterwards into other European countries, though it was only about the middle of the eighteenth century that its use became common in Britain. The turnip and cabbage were known to the Romans: these, with cauliflower, broccoli, and some of less note, form a family of plants which bear the general name of *Brassica*. By cultivation, the stem and leaves of the cabbage have in time become the most useful for food.

183. Of *Plants*, strictly so called, one of the most extensively used is the tobacco, which has never been cultivated to any considerable extent in any other country than the southern parts of the United States of America. This is an annual

plant, with leaves of about two feet long, which, when dried, and liquored in a peculiar manner, are used in various ways, all of which are supposed to be rather injurious than beneficial to the health of man. The cotton shrub grows in the same country, and in South America, Egypt, and the East Indies. Its seed-pods contain a fine down, which, in the last-mentioned country, has been used for the manufacture of a light and warm kind of cloth since several hundred years before the Christian era, and is now the material of a large portion of the clothing worn throughout the civilised world. Of this down, the United States raised, in 1850, nearly two and a half millions of bales, weighing 400 pounds each. The flax-plant, which grows in Britain and other countries, yields from its skin a well-known filamentous or thread-like substance, which, when dressed, spun, and woven, forms linen cloth. The sugar-cane, supposed to be a native of China, but now cultivated largely in the West India Islands, in Brazil, and in other tropical countries, is a plant which grows in the shape of a tapering pole to a height of between six and eighteen feet, with a long and slender leaf springing from each knob or joint, and a bunch of leaves at the top. It is propagated by cuttings, which are planted in rows: at the end of the first season, the full-grown cane is cut by the root, and a new one grows upon the stump next year; it is then necessary to plant a new cutting, as the produce would otherwise be inferior. The cane contains a matter, which is brought out by boiling; and after undergoing various refining processes, becomes the sugar with which we sweeten tea, coffee, and other articles of food. About five hundred millions of pounds-weight are annually consumed in Britain.

184. A considerable number of *Herbs*, or plants of smaller size, are useful to man as food or as medicine. Lettuce, parsley, celery, and asparagus are well known as agreeable food. Formerly, a great number of herbs were used by physicians; but the most of them have now given way to mineral drugs, which can be administered with greater precision and more certain effect. The dried flowers of chamomile, which grows in the south of England, form a tincture useful for strengthening the stomach, and for producing vomiting. The leaves of senna, a low shrub which grows in Upper Egypt, form an infusion useful as a laxative medicine for children. The seeds of the mustard plant, taken whole, are a good laxative, and, when ground, form a well-known seasoning for food. The pepper plant, of which there are sixty species, the best of which grow in the West Indies, also yields seeds, which are useful both in a whole and ground state for seasoning.

185. Of *Fruit-trees*, the most remarkable are the vine, date, fig, olive, orange, lemon, peach, plum, cherry, apple, and pear. The first four, which only grow in warm climates, were known in very remote antiquity, and are frequently alluded to in the Bible. The juice of the grape or vine fruit has been employed, from the earliest times on record, in forming wine. For this purpose, immense quantities of the fruit are produced in all the countries bordering upon the Mediterranean, and throughout the south of Europe. The apple, which is also mentioned in the Bible, is now the most prevalent fruit in Britain and the United States of America. Gooseberries, currants, and strawberries, in many hundreds of varieties, are also common fruits in Britain. A tree, which originally was confined to the southern parts of Asia, but is now cultivated in the islands of the Pacific and Atlantic Oceans, bears fruit of a large size, the inner part of which, when baked in an oven, resembles bread: this is consequently called the bread-fruit tree.

186. A few others, which cannot strictly be called fruit-trees, are serviceable to man. The cinnamon-tree, which is supposed to have originally flourished in the island of Ceylon, in the East Indies, is esteemed for its bark, which, when dried in the sun, becomes an agreeable spice. The coffee-tree, a native of Arabia, but now cultivated largely in the West Indies, is valued for its seed, which, being scorched and ground, and placed in an infusion of warm water, gives an agreeable beverage. The tea-plant, which grows in a temperate region of China, and appears to thrive nowhere else, yields leaves which, being dried and infused in hot water, give out an equally agreeable beverage. Coffee and tea, as these beverages are respectively called, were not introduced into Europe till the seventeenth century. They now rank among the chief luxuries, or rather necessaries of life, in all civilised countries, no less than seventy millions of pounds of tea-leaf being annually consumed in Britain alone. The hop, a climbing-plant, is extensively cultivated in the south of England, on account of its flowers or seed-vessels, which impart a bitter but pleasing taste to ale.

187. *Timber-trees* abound in almost all countries except those exposed to the greatest degrees of cold. Britain possesses the oak, elm, ash, beech, birch, holly, hawthorn, chestnut, yew, and many others. The oak, which has been survive a thousand years, and overspread an acre with its branches, supplies timber of a hard, solid, a kind, useful in the construction of ships, and the w of large public buildings. The pine, which grows perfection on the hills of the north of Scotland, is als

in ship-building. Britain, on account of the preference long given there to agriculture, does not rear a sufficient quantity of timber for its own use, but imports it from the North American

The Oak.

colonies, where it grows in great luxuriance. The best kinds of pine-timber are produced in Norway. The mahogany-tree grows in the West Indies, and in several parts of the American continent; it sometimes reaches the height of a hundred feet; the timber is peculiarly hard and close-grained, and capable of a high polish, so as to be very suitable for the construction of articles of household furniture.

188. The science which takes cognizance of the vegetable substances of the earth is named BOTANY. The structure and internal economy of plants fall under a distinct branch of science, termed *Vegetable Physiology*.

VEGETABLE—from the Latin *vegeo*, I grow; having the power to grow or increase in size, as plants do, and hence specially applied to them.

CEREALIA—from *Ceres*, the heathen goddess, supposed to preside over the culture and growth of grain.

LEGUMINOUS—from the Latin *legumen*, a kind of vetch or pea; a term applied to those plants whose seed is contained in pods, like the pea and bean.

ESCULENTS—from the Latin *esca*, food, or anything to be eaten; a term applied to those plants and roots which form articles of food.

FILAMENT—from the Latin *filum*, a thread. The thread-like fibre which supports the stamen of a flower is technically called the filament.

PEDUNCLE—from the Latin *pes, pedis*, a foot; the footstalk which supports the blossom of any plant.

BOTANY—from the Greek *botane*, grass or plant; hence applied to the science which treats of the nature and varieties of plants.

THE ANIMAL CREATION.

189. All parts of the earth's surface, except those exposed to intolerable degrees of cold, are peopled by *Animals*—that is, by beings which not only possess an organised structure, as the plants do, and, like them, are capable of being nourished by assimilating various other substances, but are animated by an *internal principle*, which can be traced in many very remarkable results, particularly motion from place to place, a selection of advantageous circumstances, and a power of adapting means to ends. At the head of this class of beings stands *Man*.

190. Every one has a general idea of animals: we all have seen and know something of quadrupeds, birds, fishes, and insects—for these, in some of their numerous varieties, are daily presented to our eyes. Every considerable portion of the earth is peopled by a certain group of animals, which are either calculated to exist only in the climate which there prevails, or have been prevented by some other circumstances from spreading beyond it. Besides the many kinds of animals which commonly fall under our notice, there are numberless varieties so small, that we cannot see them without the aid of an instrument called a microscope, which is designed to make minute objects visible. Wonderfully careful and ingenious provisions have been made for the support of this vast multitude of visible and invisible creatures, not one of which, however vile or unimportant it may appear to us, has been left without some mark of Almighty wisdom and goodness, either printed upon its form, or shewn in its manner of life.

191. Some animals are said to be of lower grade than others. When an animal has a great number of parts which are merely repetitions of each other, as the segments and feet of the centipede, it is considered as a simple or humble animal, in comparison with one which has only one part, organ, or pair of organs for each particular purpose. When an animal consists of but a bag or stomach, with limbs or tentacles to supply it with food, and perhaps with no aperture besides the mouth, it is manifestly framed on a very simple plan, and must be deemed humble in contrast with many others. Accompanying humbleness of grade, we generally find one or other of such peculiarities as these: that a piece of the body is separated to make a new animal, or that the young are presented in the form of

eggs, and these in comparatively great numbers; that the two sexes are found on one individual; that the young require little or no care on the part of their parents; that, the body being divided, each part will for a long time retain life, or that, a limb being lost, a new one will grow. A large proportion of the humbler creatures live in the sea, with *branchiæ* (gills) as a breathing apparatus, and it is the destiny of a vast number to be fixed to one place. It has been arranged that some animals should live on vegetable matter, while some prey on other animals. Those which form a prey to their neighbours are generally produced in great abundance. Each kind is furnished with teeth and other organs suitable for its mode of subsistence. The degree of intelligence is also appropriate to the requirements of each creature.

192. The ANIMAL KINGDOM, as this department of nature is called, has been arranged by Cuvier and other naturalists in divisions and subdivisions, according to grades in structure and the resemblances or affinities which exist among the several creatures. First, the whole is divided into four Provinces or sub-kingdoms, designated thus:

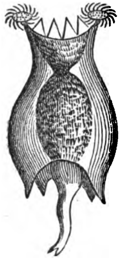
I. Radiata, or Rayed Animals,
II. Mollusca, or Pulpy Animals,
III. Articulata, or Jointed Animals,
IV. Vertebrata, or Back-boned Animals;

the first being of the lowest, and the last of the highest character. Each of these, again, has been divided into *Classes*, marked by peculiarities of less importance; these into *Orders*, with reference to still less conspicuous distinctions; and these into *Families* and *Genera;* and finally into *Species*, this last term being applied to any form which appears as maintained uniformly through a succession of generations.

193. The first and lowest Province, RADIATA, includes a vast number of animals, of simple organisation, and generally obscure habits, and all of which reside in water. The province comprehends five classes—Infusoria, Zoophytes (or Phytozoa), Acalephæ, Entozoa, and Echinodermata.

194. The *Infusoria* are animalcules, or animals invisible to the naked eye, usually found in stagnant water, or water into which vegetable matter has been *infused*—hence the name. It is supposed that the vegetable matter conveys the germs from which the infusoria arise. Of one order, *Polygastrica* (many-stomached), some are naked, some with silicious coverings. These coverings, inconceivably small as they are, have in some places been deposited in such vast quantities as to form hardened strata, or beds of rock. Another order, the *Rotifera*, occur in the most varied and grotesque forms; some

resembling eels, snakes, and horns; others twisted and bent like screws and branches of trees; while many assume the forms of tulips, egg-cups, and other shapes equally curious. Some of them are supposed to propagate by eggs; but the most do so by dividing their own bodies into parts, each of which becomes a new animal of a different shape from its parent. A great number are rapacious, and it has been observed that the occupants of two drops of water which have been brought from different places, were at peace among themselves while the drops were kept separate; but no sooner had the two drops been thrown into one, than a scene of strife and destruction was presented. How strange to reflect, that the same Being who formed the globes of space, has breathed a peculiar intelligence into specks of matter, of which thousands would require to be thrown together before they could become perceptible to the most searching human vision!

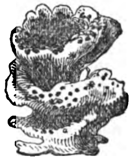


Rotifera.

195. The second class, *Zoophytes*, so named from their external resemblance to plants, comprehends several important orders. The general character is that of a polype, a small animal consisting of a stomach with tentacles to supply it with food, and of which many may be clustered together on some general frame or stalk. Of one order, *Hydroida*, the type is the well-known *hydra*, a creature usually seen hanging from a straw or twig in stagnant water, actively engaged in catching and swallowing minuter animals. When this creature is turned inside out, it goes on feeding itself as before. There is another family, represented by the *sertularia*, the chief peculiarity of which is its being enveloped in a horny case; but here a plant-like figure is assumed, on which the several polypes appear as branches.

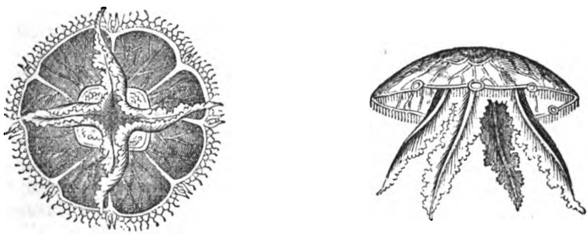
196. The order *Helianthoida*—so named from their resemblance to the popular pictures of the sun and his rays—are fleshy polypes, most of which are fixed to the bottom of the sea. An example is the *actinia*, or sea-anemone, which consists of a stomach, with a multitude of tentacles placed around the mouth, and which can gorge shell-fish of considerable size. Of another order, the *Asteroida*, we have a good sample in the *Alcyonium* (or dead-man's fingers), a pale, flabby, branched mass, often found amongst refuse from the fishermen's boats, and of very disgusting appearance, but which is, in reality, a beautiful animal when seen with all its tentacles displayed in its proper element. To the same order belong the *Corallifera*,

or coral-bearing animals, a tribe of wonderful character and great variety. From the hard bottom of the sea arises something in the form of a mushroom, fern, shrub, or tree, of a hard consistence, and full of little holes. It is, in reality, an animal, or rather cluster of animals, each occupying its little cell in connection with the rest, and working towards a common object. In the Southern and Pacific Oceans, these corals and madrepores, as they are called, are raising vast beds of calcareous or limy matter from the bottom to the surface of the sea, some of which form *reefs*, of great danger to seamen, while others have been covered with soil and vegetation, so as to become habitable islands. One kind of the Corallifera, of which there are upwards of a hundred varieties, grow from the bottom of the Red and Mediterranean Seas, in the shape of large fungous plants (plants like mushrooms or apple-tree fog), consisting of a soft porous substance, pervaded by tubes in all directions, and capable of being irritated by touch. When torn up and cleared of a certain external matter, in which their life is thought chiefly to exist, they become the well-known useful substance called *sponge*.



Coral.

197. The class *Acalephæ* (sea-nettles), embraces the well-known creatures commonly called jelly-fishes, of which the *medusa* and *beröe* are notable examples. The acaleph is a creature whose body does not contain more than four per cent. of solid matter, which may be seen making its way swiftly



A B

Medusa.

A, under surface, shewing the mouth in the centre, surrounded by the tentacula, and the ovarial chambers exterior to the origins of these; B, side-view, shewing the tentacula hanging down in their natural position.

through the water by peculiar powers of contraction, with tentacles depending from it for the catching of prey. While

of such watery consistence, it has a power of stinging, and thus mastering creatures much higher in the scale of being than itself.

198. The class *Entozoa* are worms inhabiting the bodies of other animals. One called the tape-worm reaches a length of thirty feet. The last class is the *Echinodermata*, or spiny-skinned animals. Of these creatures, the star-fish and sea-urchin are familiar examples.

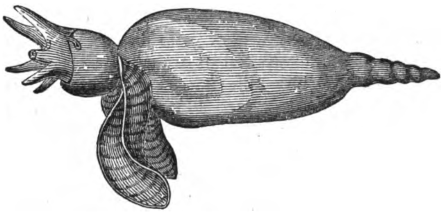
199. The MOLLUSCA, forming the second Province of the Animal Kingdom, are animals of pulpy substance, having no internal skeleton, but usually enclosed in a hard shell or shells; having pale blood, and no brain, but simply a nervous cord pervading the body. The shell of the mollusk is a membrane composed of minute cells, in which is deposited calcareous matter, the whole being secreted from the verge of the *mantle* or skin of the animal. Most of the mollusca are fitted only to live in the water. A few are useful as food. Agassiz divides them into three classes—*Acephala* (having no head), *Gasteropoda* (moving on the belly), and *Cephalopoda* (having the organs of locomotion connected with the head).

200. The *Acephala*, or headless mollusks, form the class of greatest importance, as it embraces most of the shell-fish which are appreciated for food. The *Tunicata*, forming the first order, are humble creatures enclosed in a cartilaginous envelope or coat, instead of a shell. To them belongs the family of the *Ascidians*, which have long been a favourite study of the naturalist, partly on account of a curious peculiarity in the circulation, the blood passing not always in one direction, but going backwards and forwards. The *Salpæ* are another family of much note, because the animal passes through a course of distinct forms, the third reproducing the first.

201. The second order, *Brachiopoda* (arm-footed), inhabit bivalve shells, without a hinge, the animal being provided with muscles which keep the valves together. These creatures are found by the geologist to have greatly abounded in the early ages of the world (Silurian epoch). The third order, *Lamellibranchiata* (having plate-shaped gills), or *Testaceæ*, comprehends the oyster, muscle, clam, cockle, and other bivalves commonly in use for food.

202. The class *Gasteropoda* for the most part inhabit a shell which is always of one piece (univalve), in many instances of a spiral or twisted form. They are generally of sluggish habits, moving on a muscular disc projecting from the abdomen. Most of them are marine animals; some inhabit fresh water; a few live on land, but generally in moist shady situations. Many feed on vegetable substances. Cuvier has arranged the

Gasteropods in nine orders, generally with a regard to the form of the gills or breathing apparatus. The limpet, whelk, cowry, and common snail are examples familiar to all. With this class, Agassiz connects the *Pteropoda* (wing-footed), a group of exclusively marine creatures, so called from their having two feet, resembling fins, on the sides of the neck. Among them the chief is the Clio, which haunts the northern seas in immense numbers, and, though only about an inch long, constitutes the principal food of the whale.



Clio Borealis.

203. The class *Cephalopoda* are so named from having the limbs in immediate connection with the head. They are the most highly organised of the Mollusca, some possessing the rudiment of a skeleton. All are, however, inhabitants of the sea. They are generally carnivorous, and in the early ages of the world, the chief predaceous animals in existence were huge cephalopods (ammonites, orthoceratites, &c.). The class, in our time, embraces several remarkable families, represented by the Cuttle-fish and Nautilus. The former is remarkable for an ink-like excretion, with which, when in danger from other fishes, they can discolour the water around them, so as to escape, as it were, under a cloud. The Nautilus itself only occupies a small portion of the outer part of the shell. The rest is divided into numerous chambers, connected by a small opening with each other, and in these it can produce a vacuum, and so render itself light enough to ascend to the surface.

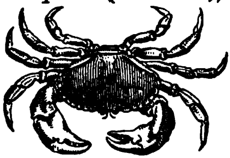
Nautilus.

204. The third Province of the Animal Kingdom is composed of the ARTICULATA, or Jointed Animals, the chief characteristic of which is that the principal families have an external skeleton of calcareous or other hard matter, divided into portions,

which are connected by joints. This is a department of the Animal Kingdom comprehending a greater variety of creatures than any other. It is divided by Agassiz into three classes—Worms (*Annellata*), Crustaceans, and Insects. The Arachnida, however, which Agassiz would place with Insects, are considered by other naturalists as forming a separate class.

205. The class *Annellata* (ringed animals) includes all creatures of the worm character, excepting those which inhabit the bodies of other animals. They obtain their class name from their bodies consisting of a series of rings, by collapsing and extending which they move forward. The first segment, forming the head, usually differs little from the rest, except by the presence of the mouth and the principal organs of sense. The blood is ruddy, but differing in character from the red blood of vertebrated animals. The sea-worm, *nais*, the lob-worm of the sandy beach, and the earth-worm; the leech; the *nereis* of the sea and centipede of the land; the marine creature named the *serpula*, which inhabits calcareous tubes on stones or upon the shells of other animals—are examples of the class more or less familiar.

206. The class *Crustacea* is divided into seven orders—*Decapoda* (ten-footed), including the Crab, Lobster, and Prawn; *Stomapoda* (having feet connected with the mouth), including the Squill and Phyllosoma; *Amphipoda* (round-footed), including the Sand-hopper, a creature often seen jumping about in search of prey upon the beach; *Læmodipoda* (throat-footed); *Isopoda* (equal-footed), of which the Wood-louse is a familiar specimen. The above form a section of Crustacea, which bears the name of *Malacostraca*, on account of their being furnished with shelly teguments of a soft nature. Another section, called *Entomostraca* (insects with shells), comprises two orders—*Branchiopoda* (having feet like the gills of fishes); *Pæcilopoda* (various-footed), a tribe of minute creatures which infest the skins of fishes.



Crab.

207. With this class are now associated the *Cirrhopoda*, which, from something doubtful in the appearance of their shells, were formerly considered as mollusks. The *barnacle*, which attaches itself by a stem to ships' bottoms and floating pieces of wood, and the acorn-shell or *balanus*, which dots the rocks exposed at low water, are familiar examples of this order. In a time of ignorance, it was supposed that a kind of geese were hatched from the barnacle.

208. The class *Insecta* embraces a very large proportion of

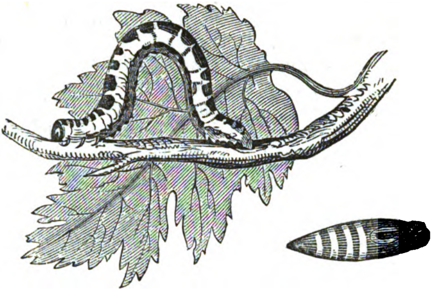
the creatures composing the animal world. The name is descriptive of the form, which, in general, appears to be nearly cut into two or more portions. The class is divided into nine orders—*Coleoptera* (sheath-winged), to which belong the Beetle, Death-watch, Cockchafer, and many others; *Orthoptera* (straight-winged), of which the Grasshopper and Locust are specimens; *Neuroptera* (nerve-winged), including the Dragon-fly, May-fly, Ephemeron, and the Termite, or white ant; *Hymenoptera* (membrane-winged), including the Ant, Bee, and some others; *Homoptera* (half-winged), including the Aphis and Fire-fly; *Heteroptera*, including the Bug, Boat-fly, and Water-scorpion; *Lepidoptera* (scaly-winged), including the numerous kinds of butterflies and moths; *Diptera* (two-winged), of which the Gnat and House-fly are examples; *Aptera* (wingless insects), among which are included sundry creatures which live upon the juices of other animals—the Flea, the West Indian Chigoe, and the Sugar-louse.

209. Insects are the most remarkable of the Articulata for their intelligence. In every part of the habitable globe, but particularly in warm climates, they are found in immense multitudes, constituting the common food of many larger animals. They are generally described as consisting of soft parts enclosed within a hard covering, never with fewer than six legs. Insects possess not only intestines, but organs for breathing, and a kind of brain. They have no voice, but are not destitute of organs of hearing, seeing, smelling, and touching. In some, the eye is very prominent, and consists of a multitude of facets, each of which is directed to a different point: of these, eight thousand have been counted in the eye of the common house-fly.

210. Insects feed on various kinds of animal and vegetable matter, and some are so voracious, as to prove destructive to gardens, forests, and fields of grain. They are generally of different sexes, the male being sometimes very different in external appearance and size from the female: in one instance (the white ant), the female attains a bulk between two and three hundred times larger than the male. The most of insects propagate by eggs, which some display great ingenuity in secreting in such places as are most likely to furnish food to the young. There are a few which contrive to dig into the bodies of other animals, even of man himself, so as to deposit their eggs in the flesh.

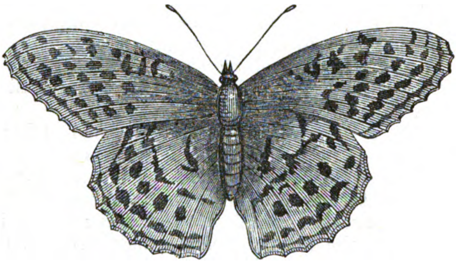
211. Several tribes of winged insects have a curious process of reproduction. The issue, for instance, of the egg of the butterfly, is not a creature like herself, but a ringed worm

called a caterpillar, which lives for a time on vegetables, repeatedly casting its skin. In time it assumes a shorter and



Butterfly in its first and second state.

harder form, and falls into a state of torpor. In this state it remains for a certain term, to all appearance dead; but at length the exterior bursts, and the butterfly issues from it—at first somewhat soft, with short wings, but soon quite equal in vigour and length of wing to its parents. In the first state it is scientifically called the *larva;* in the second, the *chrysalis;* and in the third, the *perfect insect.* These transformations



Butterfly in its perfect condition.

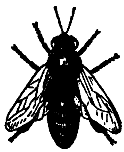
have ever been regarded with a peculiar interest by man, as supposed to bear a resemblance to those changes in his bodily and spiritual nature which he himself trusts to undergo. The ancient Greeks considered the butterfly as an emblem of the soul, and occasionally used the word *psyche,* which properly signifies the soul, to signify also a butterfly. It appears, however, that, in both of the earlier stages of the

existence of the butterfly, the rudiments of the perfect insect can easily be traced.

212. Of butterflies, many thousand kinds have been reckoned. In tropical countries, particularly in Brazil, they are seen in great numbers, and of great size, one kind measuring nearly a foot between the extremities of the wings. They exceed all other insects in beauty. Each species has wings variously coloured, and usually with great splendour. The colouring resides in close rows of inconceivably minute scales, which cover the membrane of the wing, as slates or tiles cover the wood-work in the roof of a house, and of which there are about a hundred thousand on every square inch of surface. Seventeen thousand lenses, each possessing the power of a distinct eye, have been counted in what appears one eye in this order of insects. These two circumstances, in conjunction, convey a singular impression of the bounty with which nature has lavished her labours upon creatures apparently destined for the humblest purposes; for we here find an insect gifted with perhaps a million of scales, most curiously arranged and coloured, and with between thirty and forty thousand eyes, which is, after all, but a mouthful for the support of a bird.

213. Various winged insects, when in the *larva* state, wind off from their body, by an apparatus in their mouth, a clew of viscous thread, wherewith to cover themselves when in the chrysalis state. This covering is usually called a *cocoon;* the most remarkable example being that of the silk-worm, which is turned to good account by man, in forming one of the most elegant articles of clothing.

214. The honey-bee and the ant are insects of peculiar interest, on account of their habits. Both of these species, it is well known, live in a state of society much after the fashion of the human race. A hive of bees usually contains about twenty thousand, of which from one to two thousand are males, of an inactive character, and usually called *drones.* The rest of the community are females, in an imperfectly developed state, and form the industrious portion of the race. One of each hive, considerably larger than the rest, is the only true female. She is called the *queen*, on account of the authority she exercises over the hive, and lays eggs, from which are produced not only other queens, but also drones and *working-bees;* the larva of a working-bee being capable of becoming a queen, if treated to a richer kind of food. In reality, the queen is the only mother in a hive, and all the other female bees act only as nurses for the rearing of her numberless progeny.



Bee.

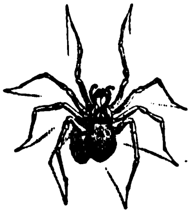
215. Bees, in common with other insects which derive nutriment from flowers, are provided with a proboscis, or long flexible snout, with which they can suck up the sweet matter which resides in the deep tube-shaped *corollæ*, or flower-cups. The matter thus sucked up is deposited in a little bag in the abdomen of the insect, and brought home. In one kind of working-bees, it assumes a waxen consistency; in another, it becomes honey. With the wax are built ranges of little cells, depending in cakes from the roof of the hive, for the reception and safe keeping of the honey. Working-bees are also furnished with bristly feet and bodies, for the purpose of brushing off the pollen of flowers and collecting it in little pellets, which they bring home in a kind of natural basket upon their hind-legs, to be afterwards mixed with honey, as food for their young in the larvous state. The honey is designed by them to serve for their own food, and it is amassed as a provision against the winter, during which they must be informed by a divine intelligence that there are no flowers. In order that their stores may go as far as possible, they always kill the males after there is no longer any use for them—a feat which they accomplish by means of their sting, a poisoned weapon situated at the hinder extremity of their bodies.

216. Ants not only shew equal or superior industry to the bees, and live, like them, in societies, but display a power of constructing habitations which far transcends the ingenuity of the bees in the formation of their cells. It is chiefly to tropical countries that we are to look for the most remarkable examples of the industry, ingenuity, and great collective power of this insect. The ant-hills of Africa and South America have been long noted for the ingenuity of their structure, some compartments being set aside for food-stores, others for nurseries for the young, and others for defence and shelter. The community is also divided into several orders, such as workers, defenders, and royal inmates, each performing their several duties with astonishing regularity and order, whence the ant has become among men a proverbial example of diligence and industry.

217. The *Arachnida* are divided into two orders—*Pulmonariæ* (arachnida with lungs), including the House-spider, Tarantula, and Scorpion; and *Trachearia* (arachnida which breathe through tubes interspersed throughout the body), of which the Mite is a well-known, though diminutive specimen.

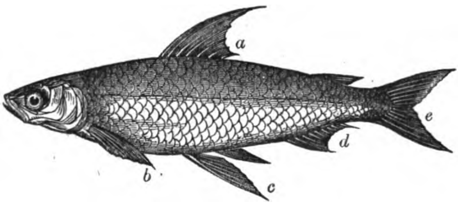
218. The lunged Arachnida are entirely creatures of prey. The spider constructs, of threads which he draws from his body, a net, which he spreads across some neglected corner within our houses, or between the branches of a bush, so as

to catch flies, which he immediately rushes upon and destroys. In the processes necessary for this great end of his existence, he displays a degree of patient perseverance which may well be held up as an example to man. When his web chances to be destroyed, he loses no time in reconstructing it, though it is a work of great labour. The scorpion is a creature much larger than the spider, and has a poisonous sting, which produces very painful effects upon those who are wounded by it. The mite inhabits decayed cheese, and other substances in the same state. Small as it appears, it is a fully formed animal, with six legs, and nippers in the mouth for eating; it propagates by means of eggs, of which it lays vast quantities.



Spider.

219. The fourth Province, the VERTEBRATA, are chiefly distinguished by a superior nervous system, centering in a backbone and skull designed for its protection. The backbone and skull are parts of an internal calcareous skeleton, on which the softer parts of the animals are, as it were, framed.



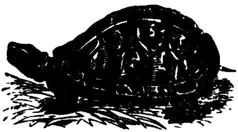
Fish.

a, dorsal fin; *b*, pectoral fin of one side; *c*, ventral fins; *d*, anal fin; *e*, caudal fin, or tail.

The province is very clearly divided into four classes—Fishes, Reptiles, Birds, and Mammalia, or suck-giving animals—of which the first reside exclusively in water, with gills for breathing; the first and second have cold blood; and the first, second, and third are for the most part oviparous—that is, bring forth their young in the form of eggs. The heart in fishes has but two cavities, and in reptiles three, while in birds and mammals, which have warm blood, this organ is in four divisions.

220. The class *Pisces* (Fishes) are fitted by gills, and generally by fins, for breathing in and making their way through the water. They are divided into five orders: *Chondropterygii* (having cartilaginous fins), including the most voracious and destructive animals of the class, the shark, ray, and sturgeon (such fishes as existed in the early ages of the world were of this order); the *Plectognathi* (having cheeks united by suture), including the Sun-fish and Trunk-fish, the *Lophobranchii* (having tufted gills), including the Pike-fish and Pegasus; the *Malacopterygii* (soft-finned), including the Carp, Pike, Cat-fish, Trout, Salmon, Cod, Haddock, Ling, flat fish of all kinds, and all fishes of the eel kind; the *Acanthopterygii* (thorny-finned), including the Perch, Flying-fish, Mackerel, Sword-fish, Mullet, and others.

221. The *Reptilia* (Reptiles), so called from their creeping mode of walking, forming the second class of vertebrated animals, are distinguished by a slow mode of respiration, which causes their bodies to be colder and more inactive than those of the Mammals and Birds. Many of them are wholly without limbs. There are four orders in this class. The *Chelonia*, or Tortoises, are enveloped in a hard shell, from which no part projects but the head, tail, and four feet. They chiefly inhabit warm countries. One kind, the Turtle, makes a delicious food in the form of soup. Tortoises are remarkably tenacious of life, subsisting for years without food, and even surviving for weeks after the head is cut off.



Tortoise.

222. The *Sauria*, the second order, are creatures of the character of the Lizard. They have long bodies with feet, and

Crocodile.

a long tail. The Crocodile and Alligator are large and powerful animals, haunting rivers and swamps in warm countries, and often making even man their prey. The Lizard Proper is a comparatively small and harmless animal. The Iguana, a native of South America, resembles the alligator in size, but

is used as food. With this family is classed the Dragon, which, instead of being a large, fierce, and winged animal, as represented by ancient writers, is a small innocent creature, possessing only a membrane like that of a bat, which enables it to make long leaps. The Chameleon is another member

Chameleon.

of this order, having the power of changing its colour. It is a small creature which lives upon flies. Reptiles of the Saurian order, but of kinds which do not now exist, have already been described under another section as amongst the earliest animals which were fitted to live upon dry land.

223. The third order, *Ophidia*, embraces many kinds of serpents, snakes, and vipers. These are the only vertebrated animals which do not possess legs: their bodies consist of a great number of vertebræ and ribs, and by contractions of these, they move in any direction they please. Many creatures of this order have poisonous teeth, which render them very noxious to man. The common viper of this country is comparatively a small creature; but in warm countries there are serpents, such as the *boa constrictor*, twenty feet and upwards in length, capable of killing and eating deer.

Viper.

224. The *Batrachia*, constituting the fourth order of Reptiles,

are creatures of the character of the Common Frog. To this order belong, besides the various kinds of frogs, the Toad, the Salamander, and the Siren. They are remarkable for possessing, at an early stage of existence, gills resembling those of fishes, which enable them to live in the water. Young frogs are then called tadpoles. In due time, lungs for inhaling the atmosphere are developed in the tadpole, which then leaves the water, and acquires the form of a frog. As living in water at one time, and afterwards on land, this order of reptiles is sometimes called *Amphibia*.

Frog.

225. *Aves* (Birds), the third class of the Vertebrata, though all produced in the egg form, are clearly pre-eminent over the fishes and reptiles in the possession of a system of respiration by which their blood is warmed, and in their having the complete or four-chambered heart. They are usually covered with feathers, and along with one pair of limbs and feet, have wings, by which most of them are enabled to fly. The class may be divided into six orders.

226. The order *Natatores*, or Swimmers, are generally fitted for living upon the sea or in rivers and lakes, having webbed feet to enable them to move over the surface, and broad strong bills to serve for making prey of the smaller animals living in the waters below. The order, however, includes creatures of very various character, from the gentle duck and goose, and the lively teal and gull, up to the albatross, which has wings measuring twelve feet from tip to tip, and is a most predaceous bird. A remarkable peculiarity of the swimming-birds is, that great numbers of them are accustomed to migrate annually from the temperate to the arctic regions of the earth, in search of food, and for the purpose of bringing forth and hatching their young.

227. The order *Grallatores* (Wading-birds) includes the Lapwing, Stork, Heron, Crane, Pelican, Snipe, Stilt, and others, all of which are remarkable for having long unfeathered legs, designed for enabling them to walk into shallow waters, there to catch their prey. They usually have long bills also, with which they search the waters for fish and reptiles.

228. The order *Cursores* (Runners) includes only a few species; the Ostrich of Arabia and Africa, the Cassowary of Asia, the Emu of Australia, and the Rhea of South America, which are generally large birds, with long limbs of great strength, but with scarcely any wings, being designed to scamper over

wide plains in search of their food. The Bustard, once common, but now rare in England, may be considered as the European representative of the Ostrich.

Ostrich.

229. The *Rasores* (Scrapers) form the fourth and a very important order. Besides the cock and his well-known and useful companion the Common Hen, it embraces the Peacock, Turkey, Guinea-fowl, Pheasant, Grouse, Partridge, Quail, and the numerous varieties of the Pigeon. In this order are found the chief birds used for food, and most of those which are considered as *Game-birds*.

Pheasant.

230. The order *Raptores* (Rapacious or Seizing Birds) are distinguished by hooked bills and strong claws. Like the Carnaria among quadrupeds, they live entirely upon flesh, usually preying upon animals weaker than themselves. The Vulture, Eagle, Falcon, Hawk, and Owl are the most remarkable families of this order. The eagle, from his great size, strength, and fierce character, has been called the King of Birds.

Eagle.

231. The *Insessores* (Perching-birds) is an order comprising many varieties, including the Sparrow, Thrush, Swallow, Nightingale, Lark, Bullfinch, Pie, Crow, and many others of the more familiar and smaller birds. The Passerinæ (Sparrow-like or field-birds) chiefly live

upon grain and insects; some possess wonderful powers of song. Among them are found two families remarkable for the beauty of their plumage—the Bird of Paradise, a native of

Bird of Paradise.

New Guinea; and the Humming-bird, which is also an inhabitant of tropical countries, and regarded as the smallest of all the feathered tribes, some varieties being not larger than the humble-bee.

232. With this order may be classed the *Scansores* (Climbing-birds), embracing the Parrot and Woodpecker. The former is remarkable for its power of imitating the human voice. They are distinguished by having two toes turned forward and two backward, to fit them for climbing.

233. The class MAMMALIA agree with birds in possessing a complete double circulation and warm blood, and with them and reptiles in breathing air, and generally living on the surface of the earth. They differ from all other vertebrate animals, not so much in producing their young alive (which is the case in a few species of reptiles and fishes), as in their subsequent nourishment of them by *suckling*—from which circumstance their class-name is derived. In their superior intelligence and adaptation to a great variety of conditions and purposes, the Mammalia may be said to stand at the head of the animal kingdom.

234. In a minor portion of the Mammalia, the young are

produced in an immature state, and are perfected in an exterior *pouch* on the abdomen of the mother. These animals, called

Great Kangaroo.

Marsupialia (Pouched Animals), now nearly confined to Australia, but once more general, exhibit, in some peculiarities, an alliance to birds. The families are of very various habits —graminivorous, carnivorous, and omnivorous, apparently

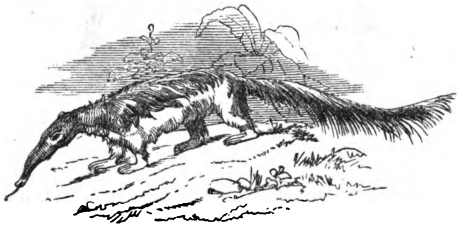
Ornithorhynchus.

representing in this grade of existence all the other orders of the Mammalia. The kangaroo, wombat, and opossum have

become familiarly known to us by means of menageries. Nearly connected with the marsupials are the *Monotremata* (so named because the excretory openings are united into one). They are exclusively found in Australia. The most remarkable species is the *ornithorhynchus*, which shews its affinity to the bird-tribes by having webbed feet and the bill of a duck.

235. Another subdivision of the Mammalia, while marked by higher characters than the preceding, must still be placed below the highest orders, the animals composing it being generally diminutive and weak, with an inferior style of dentition, and less complex brain.

236. The order *Edentata* (animals without front teeth) includes a few creatures of comparatively little importance. The Sloth, which is the chief variety, is so called from its slow motions, and apparently indolent character. It lives upon the leaves of trees in South American forests. The Armadillo is covered with scales, like an ancient warrior in his armour. The Ant-eater is well known from his habit of laying out



Great Ant-eater.

his long tongue across a path traversed by ants, till hundreds of them are upon it, when he draws it in, and devours them. Two gigantic varieties of the sloth, the Megatherium and Megalonyx, appear, from the remains of them which have been found in rocks, to have been conspicuous members of the animal kingdom long before man existed.

237. The order *Insectivora* includes the hedgehogs, moles, and shrews, all of them weak and obscure animals. Nature has provided the hedgehog with a spiny coat of armour, which, by strong cutaneous muscles, it can draw over every accessible part of the body, so as effectually to protect itself from all ordinary enemies. The mole burrows for worms in the ground, but is not, as generally supposed, devoid of organs for seeing and hearing.

238. The order *Rodentia* (Gnawing Animals), comprehending

the Squirrel, Marmot, Rat, Mouse, Beaver, Porcupine, Hare, and Guinea-pig, derive their name, as an order, from their being furnished with teeth which do not directly cut or tear, but file through or gnaw what they are disposed to eat. The powers of the common mouse in eating its way through hard wood are well known. This order of animals is also remarkable for having long hind-legs, which give them a lurching mode of walking. Most of them are afraid of other animals, and live as much as possible in obscure situations. Beavers are the most ingenious of all animals in constructing a dwelling. They cut wood near a stream, and let it float down

Beavers.

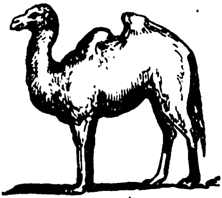
to a particular place, where they design to use it in building huts. They also erect dams to protect their huts, and in winter live in these places, much like a number of human beings living in a town.

239. Of the larger and more advanced Mammalia, a portion are fitted by nature for living in the sea, though nevertheless true warm-blooded and air-breathing animals. To fit them for swimming, the extremities are fashioned into *paddles*. There are of these natatorial or Swimming Mammalia three well-marked families.

240. The first, *Cetacea* (Whales), are the largest animals in existence. The most remarkable species, the *Common Whale*, reaches a length of seventy feet. It has two skins, enclosing a thick padding of fat, useful for keeping the animal warm in the cold arctic seas in which it lives; and to obtain this fat, for use as oil, there is a regular fishery of the whale. A horny apparatus in the mouth of the animal, used by it as a *strainer* in which to catch the small marine creatures which form its food, is in request for various uses under the name of

whalebone. The whale moves through the water by means of its paddles, aided by the hind extremities, which take the shape of a horizontally disposed tail. The *dugong* and *manatin* are lesser whales, which feed on vegetable substances. It is a mistake to call the whale a *fish*.

241. A second family of the Swimming Mammalia is composed of the Seals (*Phocidæ*), which are much smaller than the whales, and great devourers of fish. They may be considered as the tigers and bears of the sea. A third family are the Dolphins (*Delphinidæ*), remarkable for their lively habits. and for their usually being seen in large droves. Amongst them is placed the *narwhal*, one of whose front teeth is developed into a bony spear six feet long.



Camel.

242. The order *Ruminantia* (Ruminating Animals) includes many of the creatures most useful to man, as the Camel, Stag, Antelope, Goat, Sheep, Bullock, and Buffalo. They live on grass, and receive their name as an order from their habit of masticating their food twice, or 'chewing the cud.' It first descends, in a slightly chewed state, into a large paunch; thence it passes into a smaller, the inside of which is like a honey-comb, where it is made up into balls or pellets. The animal, lying at its ease, causes these balls to come back into the mouth, to be more effectually chewed. When the food has undergone this last process, it descends into a third stomach, and thence into a fourth, where it is digested. The Ruminants are distinguished as *Ungulata*, or Hoofed Animals, the foot terminating in two horny sheaths or hoofs. All are fitted to serve as food for man; some act as beasts of burden; some furnish us with milk, tallow, leather, hair, wool, horn, and other useful products.

Stag.

243. The order *Pachydermata* take their name from the peculiarity of a *thick skin* which generally characterises them. The Elephant, the largest and most sagacious of land animals, forms one family, distinguished chiefly from the rest by having a long snout, or proboscis, the design of which is to lift food to the animal's mouth. A second family is composed

of the Hippopotamus, or river-horse, the Rhinoceros, the Tapir, and the Boar or Hog—the last being the only animal of this order whose flesh is eaten by man. A third family embraces the Horse, Zebra, and Ass. These last have the entire foot enclosed in a horny sheath or hoof, which especially fits them for careering over extensive grassy plains.


Elephant.

244. The order *Carnivora* (Flesh-eaters) is composed of a great variety of important animals, most of which are beasts of prey. The Bear, of which there are many varieties, chiefly living in cold northern countries—the Raccoon, an inhabitant of North America—the Badger—the Glutton—and the Ratel, form a tribe called *Plantigrada,* from their setting down the whole foot in walking. Another tribe, named *Digitigrada,* from their walking on the ends of their toes, embraces the Weasel, Polecat, Skunk, Otter, Civet, and Hyæna. To this tribe also belongs the Dog, an animal highly useful to man, and of which there are numberless varieties. Naturalists likewise rank in this portion of the family of flesh-devourers the feline (or cat-like) races, comprehending the Lion, Tiger, Jaguar, Panther, Leopard, Puma, Lynx, and Cat. They are remarkable for the union of great strength with great lightness and agility, and for their powerful teeth and claws. These peculiarities, with a stealthy and cunning character, shew that they have been designed to subsist by the destruction of smaller animals. The Lion is commonly called the King of Beasts; but he only merits this title from his terrible look and fierce habits, and not from any nobleness of nature.


Lion.

245. The order *Cheiroptera* (Bats) are generally small animals, of insectivorous habits, and seldom seen abroad except at night. They are remarkable among the Mammalia for their largely developed hand, with a membrane between the fingers, enabling them to fly in the air in search of their prey. The vampire bat of South America sucks the blood of animals much larger than itself.

246. The order *Quadrumana* (four-handed animals) includes all the creatures commonly called Monkeys. These creatures are remarkable for the resemblance they bear to the human

race, and for the intelligence which many of them display. They are, however, different in many peculiarities of make from men, so as to shew that the one race is quite distinct from the other. The structure of the bodies of monkeys fits them for climbing, and they appear to have been designed to live chiefly amongst the branches of trees. The most remarkable species of monkey is the Orang-outang, which is nearly as big as a man, and has no tail. Another, called the Chimpanzee, an inhabitant of Guinea, in Africa, is considered the most intelligent, as it builds huts of sticks and leaves, and protects itself from the attacks of other creatures with clubs and stones.

Orang-outang.

247. Man, considered simply as an animated being, composes with his single species the last and highest order of the Mammalia. The name *Bimana* (two-handed) is usually applied to this order.

248. The science which treats of animals, their varieties, habits, and modes of life, is called ZOOLOGY. The subject is divided into several departments, under particular names—as *Mazology*, the science of suckling animals; *Ornithology*, the science of birds; *Ichthyology*, the science of fishes; *Helminthology*, the science of worms (including all kinds of snakes); *Entomology*, the science of insects; *Conchology*, the science of shells; and *Zoophytology*, the science relating to all those lower orders of animals which take the form of plants. The consideration of the structure and internal economy of animals forms a distinct branch of science, named *Animal Physiology*.

ANIMAL—from the Latin *animal*, a living creature, and that again from the Greek *anemos*, air or breath; hence originally applied to all creatures endowed with the breath of life.

ANIMALCULE—from the Latin *animalculum*, a little animal; all minute animals which require the aid of the microscope to render their parts distinctly visible, are termed animalcules.

MICROSCOPE—from the Greek *mikros*, small, and *skopeo*, I look; an instrument for looking at minute objects so as to render them distinctly visible.

AMPHIBIOUS—from the Greek *amphi*, both, and *bios*, life; applied to animals that live sometimes on land and sometimes in water.

ZOOLOGY—from the Greek *zoon*, a living creature, and *logos*, a discourse: the science which treats of, or discourses on, living creatures.

MAN—HIS GENERAL CHARACTER AND HISTORY.

249. Man has been described in the preceding section as forming a special order in the range of animated beings. He is distinguished from all others by a great superiority in intelligence, and by his possessing a moral nature. He is not, however, in every country the same creature. Europe, the western part of Asia, and the north of Africa, have been possessed, since the dawn of authentic history, by a white-skinned race, the highest in intelligence, and the most elegant in form, named the Caucasian variety, as being supposed to have originated among the mountains of Caucasus, between the Black and Caspian Seas. The remainder of Asia has been at the same time occupied by an olive-coloured race, of less intelligence and vigour of character, named the Mongolian variety, from Mongolia, a country to the north of China. A third race, of black skin, coarse features, and small intelligence, have inhabited the greater part of Africa; they are denominated the Negro or Ethiopian variety. In America, when it was discovered nearly four hundred years ago, a fourth race of a copper colour, and of no great intelligence, was found in a generally barbarous condition.

250. The white-skinned variety are remarkable for their cultivation of letters and science, and as the only race amongst which any considerable progress is made in intelligence from age to age.

251. Egypt, Arabia, Persia, Mesopotamia, Syria, and Greece, were the countries in which this race made their first advances in literature, science, art, and government. The Israelites, or Jews, descended from Abraham, an Arabian shepherd who lived nineteen hundred years before Christ, are remarkable among its various tribes for the historical circumstances narrated in the Bible. The inhabitants of Greece are also conspicuous for their high intellectual character, which they exemplified in productions of art and literature, scarcely ever since excelled. The Romans were for many centuries pre-eminent above all other nations for their great warlike power and general vigour of character. From about ten centuries before the Christian era, to six centuries after it, the nations on the northern shores of the Mediterranean, particularly the Greeks and the Romans, are found to have advanced out of, and again in a great measure sunk back into, barbarism. All that period of the world's history which preceded the sixth century of the Christian era, is regarded as the *times of antiquity*, and the people of those days are

generally called the *ancients*. After an interval of comparative barbarity, termed the *middle ages*, which extended to the fourteenth century, civilisation gradually revived; the literature of the ancients was resorted to for its refining ideas and its philosophy; the Christian religion, which had originated in Judea under the circumstances narrated in the New Testament, began to exercise its proper humanising effect; and the nations of Europe, especially those of Italy, Spain, France, Germany, and Britain, advanced to as high a state of mental culture, or even higher, than ever had been attained by the ancients. From these countries, the white race has more recently spread, with its religion, literature, science, arts, and ideas of government, to the eastern shores of America, of which continent it promises in time to become entirely possessed.

252. While the white race has been making this progress in one direction, it has relapsed, in the countries where it first flourished, into a state little superior to that of the coloured nations. In Egypt, Arabia, Persia, Mesopotamia, and Syria, the literature, science, and institutions, of which they gave the first examples, are now nearly unknown, while the ruins of their works of art alone remain to attest their former greatness.

253. Of the sciences, or branches of knowledge, relating expressly to man, that which traces the personal peculiarities of the various tribes, is termed the *Physical History of Man;* that which describes the countries occupied by the various nations, with a regard to the numbers, character, and general circumstances of those nations, is termed *Political Geography;* that which traces the different languages spoken by the different nations, is termed *Philology;* that which traces the transactions of nations throughout considerable spaces of time, is termed *History;* that which presents memoirs of the lives of remarkable individuals, is *Biography;* while that which expounds the laws that govern the production, distribution, and consumption of the results of national industry, is *Political Economy*.

254. All of these sciences and branches of knowledge are of great importance, and ought to be in some degree familiar to the mind of every individual. But there are other two, of still more direct and immediate importance, seeing that they are indispensable for the preservation of health, and the regulation of conduct. These relate to the bodily nature of man (*Human Physiology*), and to his mental nature (*Moral Philosophy*).

PHILOLOGY—from the Greek *philo*, I love, and *logos*, a discourse

or learned treatise; the love of discourse or an attachment to literature; hence specially applied to the study of written languages.

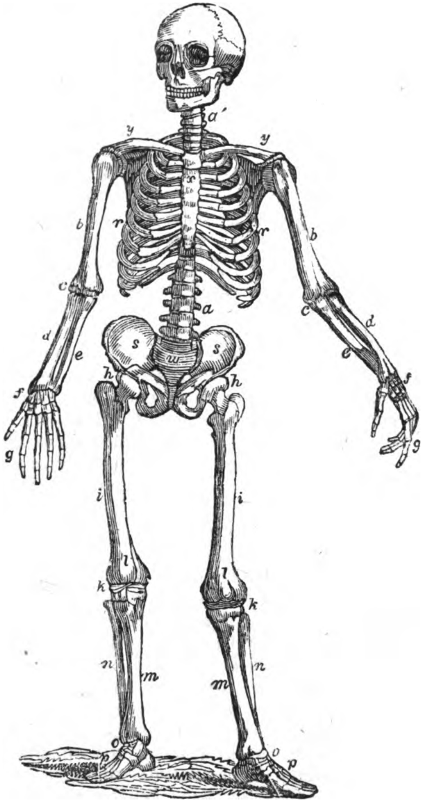
BIOGRAPHY—from the Greek *bios*, life, and *grapho*, I write; the science of life-writing.

MAN—HIS BODILY NATURE.

255. The external appearance of the human being is necessarily familiar to all. The general stature is between five and six feet; the figure, without great strength or agility, exhibits, in its upright posture, a dignity appropriate to the master-creature of the world. The infancy of man is longer than that of other animals; he does not attain his full growth till he is upwards of twenty years of age. For other thirty years, if not cut off by disease, he is in the prime of his strength. Twenty years more constitute elderliness; and if he survives seventy years in all, he is said to reach old age.

256. (*Osseous System.*) The human body is constructed upon a framework of bones, termed the *skeleton*, of which the engraving on next page is a representation. The principal part of the structure is the *spine* or *backbone*, *aa*, a column consisting of twenty-four separate bones, upon the top of which is the *skull*. The *ribs*, *r*, *r*, curve forwards from the backbone, and most of them meet in front, in a bone termed the *sternum*, or breast-bone, *x*. The *collar-bones*, *y*, *y*, extend from the *neck* to the *shoulder*, where commence the *arms*, consisting of the *humerus*, *b*, the *radius*, *d*, and the *ulna*, *e*, the two latter being joined to the humerus at the joint termed the *elbow*, *c*. At the extremity of the arm are found the bones of the wrist and hand, consisting of the *carpal* and *metacarpal* bones, *f*, *f*, and the *phalanges* or finger-bones, *g*. The backbone rests upon the *sacrum*, *w*, which is fixed between the two bones of the *pelvis*, *ss*, forming the basis of the trunk. From the bones of the pelvis proceed the thigh-bones, *h*, *i*, constituting the upper portion of the limbs. At the knee, where there is a small detached bone called the *patella* or *knee-pan*, *l*, commences the *tibia*, *m*, usually called the leg-bone. This is supported by a smaller parallel bone, termed the *fibula*, *n*, which, though not connected with the knee-joint, unites with the tibia in forming the ankle, *o*. At the ankle-joint the leg is connected with the foot, *p*, which consists of a number of small bones, and forms the basis of the whole body. The bones in the human skeleton are two hundred and forty-eight in number, each being fashioned in a way suitable to the purpose which it serves. They are

of a hard white substance, composed of lime, with a small proportion of animal matter.



Human Skeleton.

257. Upon this framework, which, not being intended to be seen, possesses no qualities pleasing to the eye, the whole remaining substance of the body is arranged and supported.

258. (*Muscular System.*) A great portion of the soft substance of the body consists of what is termed fleshy or muscular fibre.

The mass of muscular fibre is divided into upwards of four hundred bundles, singly denominated muscles, varied in size and strength according to the purposes which they are designed to serve. Muscles may be described as bundles of soft red fibres, of a cylindrical form, and running in a parallel direction. In the limbs, where the chief muscles of motion are placed, the two extremities are attached to parts which have a joint between them: when the mind desires to exert one of the limbs, it sends a command to that purpose through communicating nerves, and the muscle expands, contracts, and moves in the manner desired. All the muscles along the exterior of the body are thus under the control of the mind; but, in the interior, there are muscles necessary for the circulation of the blood, and the digestion of food, which are necessarily exempt from the will, because their functions are required at all times, in sleep as well as in our waking-hours. These are termed Involuntary Muscles.

259. (*Nervous System.*) The whole surface of the body is pervaded by fine cords, called nerves, which communicate with the brain and spinal marrow, and serve at once to convey the information of the senses to the mind, and to transmit the will of the mind to the muscles. The brain itself, the spinal marrow, and the nerves, are collectively called the Nervous System, because they are apparently united in one order of functions. The nerves are of parallel minute white fibres, each enclosed in a cellular sheath, and consisting of two parts, one of which serves for sensation, and the other for motion.

260. The brain is a white pulpy mass, placed in the cavity of the skull. It is thready or fibrous in texture, and amply supplied with blood-vessels. Being, as ascertained by observation, the organ of the mind, it is protected with all the care due to so important a functionary. The skull which covers it is an arch of the strongest construction, composed of several parts, united by tooth-like or jagged edges, called sutures, which fit into each other, so that, if an injury does take place, it is likely to stop short at one of the joinings. The brain has an interior division, which separates the principal mass from a smaller portion at the back; this smaller portion is termed the cerebellum (that is, the little brain). It is also continued in a long cord down along an opening in the column of the spine; this is usually called the spinal cord, or marrow. The least injury to the spinal cord—even so much as the prick of a pin—causes death.

261. The nerves which communicate with the senses, the lungs, and the stomach, originate in the brain; those required for the motion of the extremities, come from the spinal cord.

Another system of nerves, called the Sympathetic, which cannot be observed to have any direct connection with either the brain or the spinal cord, are seated in the breast, and are supposed to give the power of motion to the involuntary muscles.

262. Perception of the external world is communicated to the organ of thought by the senses, which are five in number:

263. *Sight*, or perception of the forms and colours of objects, is effected by the eye, the external appearance of which is well known. The pellucid ball of which the eye consists is obscured all over the front, except in one small part (the *pupil*), through which the appearances of things pass into the interior. At the back of the ball, opposite to this aperture, is a net-like membrane (the *retina*), upon which these appearances are represented, as in a looking-glass, their size being reduced by an intermediate lens. The retina is an expanded nerve, which, immediately behind, collects into the usual form, and communicates to the brain.

264. *Hearing*, or the perception of sound, is in like manner effected by a nerve spread out upon a membrane called the *tympanum*, which stretches, like the cover of a drum, across the hole within the ear. Sound is a peculiar agitation of the air, and this agitation acts upon the tympanum in the same manner as it is often found, when cannon are fired, to act upon the windows of a house; that is to say, it shakes the tympanum, the nerve of which conveys a report of every fine peculiarity of the impression made upon it to the brain. Connected also with the tympanum, there is a number of small cells, which are supposed to reverberate the sound, and heighten the impression carried by the nerve to the great centre of perception.

265. *Taste* chiefly resides in nerves pervading the surface of the tongue, the skin of that membrane being pierced with numerous pores, to admit substances to a contact with them.

266. *Smell*, in like manner, resides in nerves beneath the skin of the interior of the nostrils.

267. *Touch*, or the perception of the contact of objects, resides in nerves which pervade the whole surface of the body, but are nowhere so numerous or so fine as in the points of the fingers, which have evidently been designed as the chief organs of the function of this sense.

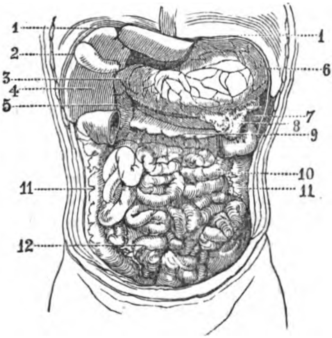
268. (*Sanguineous System.*) The whole body, not exclusive of the bones, is pervaded by a red fluid, termed the *blood*, which circulates by means of vessels or tubes, which at their extremities are inconceivably small. The organs necessary for propelling this fluid upon its course through the body,

and the organs required for communicating to it the food and air necessary for sustaining its vital character, are placed within the cavity of the ribs, in the upper part of the body. The chest, as this cavity is termed, is divided from the lower region of the body by a horizontal muscle, the diaphragm, which rises and sinks according as we are drawing or expelling our breath. The right side of the chest is divided from the left by a thin membrane, which separates into two layers at the back part, forming a canal, through which the gullet passes to the stomach. In the left cavity are situated the heart and left lung; the other side is entirely filled by the right lung. The *heart* is a strong muscular bag, the sides of which are from a quarter to half an inch thick, and are composed of circular and longitudinal fleshy fibres. The use of this membrane is to act as a force-pump for sending the blood through the various channels of the body: it may be likened to the water-works which send water through a town in pipes. It has two divisions, between which a strong partition exists, and each of these is subdivided into two cavities, called *auricles* and *ventricles*. The right side of the heart has its auricle and ventricle, and the left has the same. By the contraction of the *left* ventricle, the blood is sent into vessels, called *arteries*, and carried by them to every part of the frame. The blood, thus distributed, is re-collected by another system of vessels, termed *veins*, which bring it back to the *right* auricle of the heart, from which it passes into the right ventricle. The blood has now passed through every portion of the body, and this is called the *first* or *primary circulation*. From the right ventricle, the blood is transmitted by arteries to the lungs, circulates through them, and is again collected by veins, which carry it to the left auricle of the heart. From this it passes into the left ventricle, the point from which it started, and is distributed anew over the frame. This passage through the lungs is called the *secondary circulation*. Every emission of the blood from the heart is felt even at the extremities, and is termed a *pulsation*. The entire quantity of blood in a full-grown person is estimated to be from twenty-four to thirty pounds.

269. The *lungs* are the organs of respiration or breathing. They are of a light, elastic, spongy texture, being little else, indeed, than an interwoven series of air-tubes, air-cells, and blood-vessels. The air, inhaled by the mouth, enters a large tube called the *windpipe*, which divides at the upper part of the chest into two branches (the bronchial tubes), one of which goes to each lung, and separates into innumerable smaller branches through the whole extent of the organs.

The terminations of these air-tubes are so small as to be indistinguishable either by the eye or glass, and they mix intimately with the equally minute ends of the blood-vessels. This admixture is for the fulfilment of the purpose which the lungs serve in the system. One of the nutritious and vital principles which the blood has to impart to the body is oxygen. After it has done this during the primary circulation, it is brought by the secondary circulation to the lungs, and there, being brought into close contact with the air-tubes, it extracts from them the oxygen of the atmospheric air, and returns immediately to the heart to be circulated, and give out its absorbed oxygen anew.

270. (*Digestive System.*) Beneath the diaphragm are situated the *alimentary organs*, consisting chiefly of the *stomach* and *intestines*. When food has descended through the gullet into the stomach, it is there subjected to the influence of a fluid termed the *gastric juice*, which, in ordinary circumstances, has the power of dissolving the most solid meat. The process called *digestion* is the reduction of the aliment, by the solvent properties of the gastric juice, to a whitish half-fluid substance called *chyme*. In this state it passes out of the stomach by the lower opening named the *pylorus*, which possesses a sensitive power, enabling it to reject the matter not operated



Interior of the Body.

1. Diaphragm. 2. Gall-bladder. 3. Pyloric end of Stomach. 4. Right Lobe of Liver. 5. Duodenum. 6. Great end of Stomach. 7. Spleen. 8. Piece of Gaul, or Omentum. 9. Pancreas (Sweetbread). 10. Small Intestine (Jejunum). 11. Great Intestine (Colon). 12. Small Intestine (Ilium).

upon by the gastric juice. In the upper part of the intestines, called the *duodenum*, the chyme receives a fluid from the liver

termed *bile*, and another from the pancreas (or sweet-bread), called the *pancreatic juice*, which form it into *chyle*. In this state it is absorbed by innumerable minute vessels termed *lacteals*, and passes upwards through the chest by a long duct (the *thoracic duct*), till it is ultimately poured into one of the veins of the neck, and afterwards thoroughly mixed with the blood in the lungs, to nourish the body. All the remainder of the food not acted upon by the gastric juice is expelled from the body by the *intestines*. These, in form, do not resemble the stomach, which is a large bag, but are canals, varying from one to two inches in diameter. They are divided by anatomists into six portions, termed the *duodenum*, *jejunum*, *ilium*, *cæcum*, *colon*, and *rectum*, the last being the terminating portion.

271. (*Secretory and Excretory Systems.*) After the blood has received, by the process described, the essence of the food, besides the general purpose of supplying vital nourishment to the frame, it performs several obscurer, but not less important functions, termed *secretions* and *excretions*. The principal secreting organs are the *liver*, the *pancreas*, and the *salivary* and *lachrymal glands*. The liver is a large organ, of a dark colour and soft consistence, situated in the upper and right side of the intestinal cavity. It is remarkable for being pervaded not only by arteries, but by the large vein which brings the blood from the lower extremities to the heart. It is not absolutely certain which of these circulations, the venous or the arterial, secretes the bile. The pancreas is a small body, resembling a dog's tongue in shape, and lying close upon the stomach. Its only purpose is to secrete the fluid which assists in converting the food into chyle. The salivary glands are placed in and around the mouth, and pour out the saliva to assist in the mastication of the food. The lachrymal or tear glands are situated in the inner corner of the eye-socket; without being constantly wetted by that fluid, the eye would be incapable of motion, and liable to constant injury from the sun and air. Many other small secreting bodies exist, for the purpose of moistening the surfaces on which they are found; as, for example, the bronchial glands in the air-tubes, the mucous glands in the bowels, and the glands below the skin for secreting the fat, which serves as a protection to the frame. In all these secreting organs, we see that there is a fluid formed, but by what process of separation from the rest of the blood, we cannot comprehend.

272. The principal excretory organs are the *kidneys*, the *skin*, and the *bowels*. The bowels simply form a canal for carrying off the refuse of the food; but the kidneys and skin secrete and

remove what appears to be a refuse of the blood. The office performed by the skin is to pour off what is termed the insensible perspiration, or *sweat*.

273. (*Preservation of Health.*) Health, the greatest of all earthly blessings, depends on the body being kept in such a condition as to allow the whole of the organs to exercise their functions in the way intended by nature. Disease, on the contrary, arises either from an injury to the structure of the organs, or from a derangement in their functions. Death, occurring before old age, if not occasioned by original deficiency, is invariably the result of accidental injury or derangement.

274. It is not, of course, within the power of individuals to remedy original weakness or deficiency; neither can they make sure of avoiding the numerous diseases which extend by contagion and infection. It is possible, however, by knowledge and care, to do much for the preservation of health and prolongation of life in ordinary circumstances.

275. In the first place, to prevent injuries to the structure of our bodies, a knowledge of the laws of nature is of great service. We ought not only to know, what is known to very young children, that fire burns, that hot water scalds, that a fall from a considerable height will severely hurt us, and that edge-tools will cut the fibre, and give us much pain; but we ought to become extensively and systematically acquainted with the laws under which the material world is conducted, so that, while they are in general acting, as designed by a kind Providence, for our advantage, we may so act in regard to them as to prevent their operating occasionally, as they are apt to do, to our injury or destruction.

276. In the second place, to prevent the dangers arising from the derangement of the functions of our bodies, a knowledge of the laws of these functions is necessary. Four things, above all others, are required for keeping the organic structure of the body in a healthy performance of its functions. These are—*air*, *food*, *exercise*, and *cleanliness;* and all must be administered under proper regulations.

277. *Air* is only in a proper state for supporting the organic functions when it has a fifth of oxygen in its composition—that is, in its usual state, as found in the atmosphere. In a room which does not communicate freely with the open air, we soon reduce the quantity of oxygen: *every breath we draw in such circumstances is detrimental to health*. Hence, all sitting and sleeping apartments should be large and high in the ceiling, or else should have a constant communication with the open air. Churches, schools, factories, and all places where multitudes assemble, should be well ventilated. The air, however, is

nowhere so wholesome as out of doors; and there, accordingly, every human being should spend a considerable portion of every day.

278. Wholesome *food* is the second great requisite for health. Of the numerous articles of food, some are not easily digested, as pastry, dried and pickled animal food, oily dishes, and fruits, especially those which consist of the kernels of nuts, as filberts, almonds, and castanas. These, being likely to derange the stomach, and occasion pain, ought to be avoided, or only indulged in very sparingly. Of the beverages commonly in use, all those which contain alcohol in large proportions, as wine, brandy, gin, and whisky, are, especially in large quantities, hurtful to the digestive powers. When a judicious selection of articles of meat and drink has been made, it is still to be remembered that a certain quantity is all that nature demands. If, under the influence of a false appetite, we eat or drink more than is required for sustenance, we overload and embarrass the stomach, and prepare for ourselves many serious evils.

279. While we thus take care to supply the blood with what it requires for the support of the system, we must also adopt the necessary measures for enabling the same fluid to perform the functions assigned to it.

280. For this purpose, moderate *exercise* is necessary. The direct object, let us observe, of *supply*, is to allow of *waste*. As fast as the body is taking in new substance, it is giving off something equivalent; and thus a perpetual freshening flow is kept up. Now, in a state of inactivity, this flow is too languid. A certain animation of mind, and a certain exertion of the muscular system, are necessary for keeping it up; for the muscles, when exerted under the influence of a willing and sprightly mind, take in fresh substance from the blood, which thus becomes appetised for new nutriment. The general design of this part of the animal economy is manifest. We were designed to *labour*—to make our bread by the sweat of our brow. We have therefore been provided with organs calculated to perform labour. When these organs are used in the way ordained by nature, namely, in a moderate exercise, her intention is fulfilled, and health is the consequence. When, from indolence or bad habits, we do not exercise our bodily frames, infirmity and ill health necessarily ensue. It is chiefly in the upper ranks of society, and more particularly among the female sex, that the consequences of neglect of exercise are observable; but much injury is experienced from the same cause, by individuals who are kept, during too large a portion of the day, at sedentary employments. When,

in addition to imperfect exercise, there is a want of pure air, the evil consequences to health are proportionally increased. On the other hand, the mind and body ought not to be exercised above their strength, for by such means either may be so injured, that death will ensue.

281. The fourth requisite for health is *cleanliness*. Bathing, entire or partial, and frequent and regular changes of apparel, are necessary for the preservation of the skin in a fit state to perform its excretory function. Not knowing this, or from bad habit, many individuals do not wash themselves sufficiently often, and hence not only render their persons less healthy and more liable to disease, but become unseemly and disagreeable to others. The cleanness of our clothes, however humble, is equally necessary; and our apartments should be kept dry, and regularly swept, and well aired. As with our persons and houses, so with the streets and towns we dwell in; they should be daily cleaned, and no putrid matter or stagnant water be allowed to collect in their vicinity. It is of great importance to form habits of cleanliness in early life. When thus formed, they soon cease to appear troublesome, and are scarcely ever after neglected.

OSSEOUS—from the Latin *os, ossis,* a bone; bony, or partaking of the nature of bone.

SANGUINEOUS—from the Latin *sanguis*, blood; belonging to, or partaking of, the nature of blood.

NERVOUS—from the Latin *nerva*, or Greek *neuron*, a cord or sinew; hence applied to the nerves, from their cord-like appearance.

DIGESTIVE—from the Latin *dis*, asunder, and *gestus*, carried or conducted; the term is applied to those functions of the stomach by which the food is digested, or taken asunder, so that the nutritive portion may be appropriated to the support of the body.

DIAPHRAGM—from the Greek *dia*, through, and *phragma*, an enclosure; applied to the muscular partition which divides the interior of the body into two separate enclosures.

SECRETORY and EXCRETORY—from the Latin *se*, aside, *ex*, out of, and *cretus*, sifted or divided: hence secretory is applied to organs which separate or set aside certain fluids of the body for particular purposes, such as the gastric juice, which is a secretion; and excretory to those organs which throw certain fluids out of the system altogether, such as perspiration, which is an excretion.

MAN—HIS MENTAL NATURE.

282. The brain has been already mentioned as the recognised seat of the mind and the centre of sensation. By this it is not meant that the brain is itself the mind, but merely a material organ, charged by Almighty power with the functions of the mind, which, in itself, we are taught to regard as a spiritual

and distinct essence, destined to survive the dissolution of all matter whatever.

283. When we consult consciousness, we feel as if the mind were a scenic chamber like the camera obscura, into which the senses are constantly transmitting pictures of what is presented to them in the external world, and through which, even when the external senses are at rest, there is a perpetual flow of the recollections of former images, which we will sometimes vainly endeavour to interrupt or banish. We also become conscious that this something within us has a power of representing to itself things which may or may not be, of throwing them into new and more striking arrangements, and investing them with attributes of more than earthly beauty and sublimity. The mind, likewise, is felt to be that in which we feel affected regarding the various things and actions presented to our notice, and which governs our conduct in daily life.

284. While thus, in one respect, a single and indivisible thing, it may be divided into various instincts or faculties, each of which will be recognised by us as in some measure independent of the rest, and as possessed by various individuals in various degrees of power or activity, so as to give rise to that variety of talents and dispositions which is observed amongst mankind. These faculties may be primarily divided into two great classes—the faculties of the intellect, and the affective or sentimental faculties; the one class having chiefly to do with knowledge, the other with conduct.

285. The intellect, again, appears to comprehend two orders of faculties.

286. The order of intellectual faculties earliest developed in our minds, comprehends those which are limited expressly to the attainment of knowledge, and are therefore usually called the *Knowing Faculties*. They are—the faculty of language, the faculty for observing external objects, the faculties for observing the qualities of external objects, as their *form*, *size*, *weight*, and *colour;* and finally, the faculties for observing the relations of external objects, as their *place*, *number*, *order*, *action*, *time*, and *sound*, the relations of the last being what constitute music.

287. The other class of intellectual powers, usually not fully developed at so early a period of life, are denominated the *Reflecting Faculties*, being two in number. One may be called the faculty of *Comparison*, because its office is to call the ideas of various objects and actions together, and shew their difference and resemblances. This is the power chiefly exercised by the poet, the wit, and the orator; in whose writings and sayings, much of our pleasure depends on the

ingenuity with which ideas, usually considered as distinct, are shewn to have relations of some sort to each other. When these ideas are alike elevated, poetry is the consequence—when one is elevated, and the other mean, the result is comical and ludicrous.

288. The second of the reflecting faculties is *Reason*—in other words, the faculty for observing *cause and effect*, or necessary consequence. It is the noblest of all the intellectual powers, and that which chiefly distinguishes man from the lower animals. Gifted with this faculty, man traces, in certain regular causes, certain necessary results, and thus acquires a great influence over his fate. For instance, by observing that a particular kind of conduct is attended with painful consequences, he is enabled to avoid that kind of conduct, and consequently to escape its effects. In its highest forms, this faculty causes men to become distinguished as philosophical inquirers. It also enables men to act readily and wisely in critical circumstances.

289. The Affective Faculties are those functions of the mind by which we manifest and experience certain well-known feelings. Some of these feelings may be called Moral, because they incite us to good actions. Others may be termed Selfish, because they regard immediate gratification for ourselves, or things connected with our own interests.

290. First among the moral sentiments stands *Veneration*, which inspires respect for those persons and things which are more worthy than ourselves—especially the DEITY, who is the author of nature, and has given us all the blessings we enjoy. Next may be reckoned *Benevolence*, which prompts us to do all in our power to promote the comfort of our fellow-creatures, and makes us willing to forgive those who offend us. *Justice* is entitled to the next rank: by this sentiment, otherwise called the *Conscience*, we are constrained to render to our fellow-creatures what is their due, or to repent having done otherwise; it also prevents us from violating any right of theirs, or, if we do violate such rights, it fills us afterwards with bitter self-accusations, and incites us to do what we can to repair the wrong. The exercise of these three sentiments is enjoined in the Scripture text, which tells us that practical Christianity consists in doing justice, loving mercy, and walking humbly with God.

291. A second order of sentiments are less exalted than these, but tend much to grace the human character, to contribute to our pleasures, and to fit us for our earthly duties. It includes *Firmness*, which gives us constancy under all, but particularly difficult, circumstances—*Hope*, by which we

are sustained under afflictions, and cheered on in the path of life—*Wonder*, by which we enjoy the contemplation of marvellous things, persons, and events, real and fictitious —the *Sentiment of the Beautiful*, which gives a taste for the finest productions of nature and art—the *Sentiment of the Ludicrous*, by which we enjoy every grotesque object, whimsical thought, and droll occurrence—and the *Impulse of Example*, by which we are led to imitate features of person, character, and conduct, which are set before us.

292. A third and lower order of sentiments comprehends *Self-esteem*, by which we are led to entertain respect and admiration for ourselves—the *Love of Approbation*, through which we become solicitous of the respect and admiration of others—and *Caution*, which prompts us to guard against evils which may or may not exist.

293. The last and lowest order of feelings embraces the *Love of Life*—the *Love of Food*—the *Desire of the Society of the Opposite Sex*—the *Love of Children*—the *Love of Friends* —the *Love of Places*—the *Disposition to Oppose and Defend* —the *Disposition to Resent and Destroy*—the *Disposition to Conceal*—the *Disposition to Acquire*—the *Disposition to Work*—and the *Disposition to Concentrate the Mind upon Particular Subjects of Reflection.*

294. The intellectual faculties operate and manifest themselves in certain modes, to which particular terms have been applied. The simplest operation of the Knowing and Reflecting Faculties is *Attention*, which is necessary to interrupt the flow of thought which is at all times passing through our minds, and to qualify us for observing and reasoning upon anything brought before us. The next, to which attention is a necessary preliminary, is *Perception*, by which our faculties take cognizance, each in its own way, of the objects of nature. The power which they have of remembering objects formerly presented to them, is *Memory*. When they operate without the things being present, and fill the mind with images as vivid as if actually seen, the act is called *Conception;* and the individuals whose minds are most active and lively in thus bodying forth unseen imagery, and giving it new arrangements and attributes, are said to manifest *Imagination*. That natural and almost involuntary operation of the intellect, by which one idea recalls another, in consequence of their being connected with each other, is termed *Association*. The imperfect and confused operation of the mental faculties in sleep, is the well-known phenomenon of *Dreaming*.

295. Each of the faculties, whether of the intellectual or the affective order, experiences gratification in being exercised.

Every one of them has reference to some circumstances in our present state of existence, and a legitimate mode and extent of operation. The knowing and reflecting faculties, when rightly directed, render us intelligent beings. The moral sentiments, when not carried to extravagance, give us those impressions of religion and virtue which constitute happiness in the present world, and prepare us for a better. The second order of sentiments furnish us with many innocent enjoyments, which are only reprehensible when pursued too eagerly. In the third order, we find inferior motives for virtue in self-respect, and the desire of the good-will and approbation of our fellow-creatures, but which are highly useful where superior motives are insufficient. In their excess, these sentiments produce pride and vanity; the one being an undue satisfaction with ourselves, while the other is an undue anxiety for the praise of others. The fourth order contains propensities necessary for the preservation of the individual and the continuation of the species, but which are liable to great abuse, and when abused, lead to many evils. Among good people, they are controlled by reason, which presents a view of the miserable consequences of their abuse, and by the moral sentiments, which prompt to opposite courses of conduct. There are none, however, who succeed in perfectly regulating these impulses; and hence all men are said to be naturally wicked.

296. The sentiments can act singly, or in combinations. For instance, veneration may simply render us pious; self-esteem added, may make us very conceited of our own attainments in religion, and very contemptuous of the religious opinions of others. In the same way, an excessive love of approbation being united to benevolence, may make us ostentatious of our good deeds. So, also, a powerful feeling of resentment, in connection with conscientiousness, may produce great cruelty in punishment. The moral sentiments must act in purity, or they give us little merit. The lower sentiments must also be trained to act in obedience to the moral sentiments, and under the direction of enlightened intellect, or they will lead us to do much evil. In general, our faculties remain in a state of tranquillity or insensibility, till something occurs to awake them; and hence many err more than others, merely in consequence of being in circumstances to have their lower sentiments more frequently roused.

297. An extended knowledge of the faculties of the mind, and their various powers and tendencies, is calculated to prove of great service to every one. It will fully satisfy all, that happiness (while in its highest form derivable from sources

disclosed to us by our *religious faith*) mainly depends, in all its ordinary manifestations, upon the following conditions:

298. *First.* The moderate exercise of the intellectual faculties in the business of life, and in the study of the works of nature—making them a source of enjoyment, without giving them greater labour than they are naturally fit for.

299. *Second.* The control of the inferior feelings, which, in their excess, produce crime and misery.

300. *Third.* A watchfulness over motives, guarding particularly against self-esteem and love of approbation, which often assume very plausible disguises, and also against undue resentments, which invariably lead to misery. And,

301. *Fourth.* A constant obedience to the moral sentiments, as those by which alone we can become amiable in the eyes of men, or acceptable to God.

QUESTIONS FOR EXAMINATION.

1 and 2. What are people who have never moved from home apt to think about the extent of nature? What do they find when they begin to travel? At night, do we see all the stars that exist?

3. What hinders us from seeing the whole surface of the earth at one time? If the earth is round, why does the part we see seem flat? How may we render the roundness of the earth sensible? How large is the earth? How much of it is land? How came men to be divided into states and nations?

4. Are there other globes like ours? What are they called? What is the moon? Are there other moons? What is the sun? What is its size? How far is the earth from it? How long would it take to reach it, at the rate of a mile a minute? How many times further than the earth is the most distant planet from the sun? Do the sun and planets occupy the whole heavenly spaces? What are the stars? How may more stars than the eye sees be brought to view?

5. What do all the distinct stars that can be seen by the eye and by the telescope form? Is this the whole universe of stars? What is seen far away beyond the furthest stars of this cluster? How do we know that they are stars? Explain the words Nature, Planet, System, Telescope.

6. How many stars are seen by the naked eye? How are they classed? How many are of the first magnitude? How many of the second, and of the third? How have they been grouped?

7. What is a group of stars called? Give the names of one or two particular groups.

8. Which is the largest star? Is it the nearest? How far off is the nearest? and Sirius? When did the present light of Sirius leave it? How far off are the other star-clusters?

9. Why do we see more stars in some parts of the heavens than in others? Give an illustration from objects on the earth. What makes the Milky-way?

10. What is the effect of a telescope on some stars? What is the difference between a *binary system* of stars, and two stars close together? Have all stars the same tint? Have all the stars a constant appearance? Are the changes irregular or periodical? Explain galaxy.

11. What is meant by the *solar system?*

12. Name the large planets in order. Where do the small planets move? Explain Planetoid. What shape have the circuits of the planets?

13. What other bodies than planets belong to the solar system? Describe the appearance of a comet. Have all comets tails? How do their motions differ from those of planets? Is the number of comets known? Are the periods of any known? Name one or two.

14. State the size of the chief planets, as compared with the earth. Which of them have moons, and how many?

15. Give the several distances of the planets from the sun, and the periods of their revolutions.

16. What are sometimes seen on the sun's surface? What is thought to be the nature of the spots? What use has been made of them? What two motions have planets? In what direction? Explain Planetoid, Comet, Luminary, Satellite, Atmosphere, Axis, Phenomenon.

17. State the diameter of the earth, the height of the atmosphere, the time of the earth's revolution round the sun, and of its revolution on its axis.

18. What is the use of the circles and lines drawn on globes and maps?

19. Does the earth turn *east* or *west?* What were the heavens imagined to turn on? What were the ends of the imaginary axle called? Why is the north pole placed at the top of maps?

20. Where is the equator drawn? What is a degree, and the length of it? How are meridians drawn? How many degrees are there between the equator and either pole? Where are the tropics and the polar circles drawn? and how are they named? What is the ecliptic, and where is it properly situated? When are the days and nights of equal length?

21. Is the drawing of these lines a capricious matter? Why should the tropics be drawn $23\frac{1}{2}°$ from the equator, and not at some other distance? What does the stooping of the earth's axis produce? Shew with a hand-globe, or other round object, and a candle set in the middle of a round table, the positions of the earth at the different seasons. When the earth presents the Tropic of Capricorn towards the sun, where is it mid-summer?

22. In what region or belt of the earth is the sun's heat greatest? Why is the heat less as we advance north or south? What depends upon these gradations of warmth and cold?

23. How fast does a place at the equator move as the earth turns round? How fast in the British islands? Why this difference? Explain the cause of day and night. When a part of the earth's surface turns within sight of the sun, what does it make? When the place comes directly opposite the sun, what is it? What makes sunset? When the sun is setting to us, what is he doing to some other parts of the earth?

24. Have all places, then, the same time or hour? Are the clocks at places west from us before our clocks, or after? How many minutes of difference does a degree to the east or to the west make? In what direction must we go, and over how many degrees, in order to come to a place where it will be one o'clock when we have it only noon? Name a place where it is midnight when we have it noon.

25. What happens within the polar circles? How long-continued sunlight is there anywhere on the globe? Explain the words Pole, Equator, Meridian, Tropic, Arctic, Ecliptic.

26. What is the size of the moon? and the time of her revolution? In what time does she turn on her axis? How many motions has the moon? Whence comes the light of the moon? How are the moon, the earth, and the sun situated at full moon? at new moon? at quarter full? What are the variations of the moon's appearance called?

27. What causes an eclipse of the sun? and of the moon? Why does not every new moon eclipse the sun? and the earth eclipse every full moon?

28. What is the appearance of the moon's surface in a telescope? What is the character of the mountains? Of what things is she entirely destitute? What effects has she on us? Do her changes change the weather?

29. What are the subjects of astronomy? Explain Phase, Orbit, Eclipse, Astronomy.

30. What do we call the substances of which all bodies are composed? Is air matter? How does air differ from a stone? Is there any place that we can say there is no matter in?

31. What is matter subject to? Mention one of the most important laws or properties of matter? What is the most universal kind of attraction? In what circumstances does it act? What is the law of gravitation in respect of size?

32. What is it in respect of distance? How is the distance measured? If the distance between two bodies is made six times greater than it was, how much less will the attraction be? We know with what force a certain stone at the earth's

surface is drawn towards the centre; with what force would the earth draw it, if it were at the distance of the moon?

33. What is weight? Why is one body heavier than another body of the same size? What makes a body fall? What is the direction of the fall? Does a body fall perpendicularly to the side of a hill? What is meant by *down*? Is *down*, then, in the same direction on all parts of the earth's surface?

34. Why do we not see one stone drawing another towards it? How may the attraction of a mountain be seen? and of a large ball?

35. Is a stone as heavy at the top of a mountain as at the bottom? Could we see the difference by weighing it with a scale-beam and weights? Why not? Why are bodies lighter at the equator than at the poles? What else is altered by the same cause? Is the seconds pendulum made longer or shorter as we proceed northwards from the equator?

36. How does gravity make a liquid dispose itself? How do solids differ in this respect? Where do all the attractions upon the particles of a solid body seem to be united? What point in a body seeks to be lowest?

37. Where is the centre of gravity in regularly shaped bodies? In irregular? What causes bodies to tumble? What shape prevents tumbling? Why is a high-loaded coach more easily upset than a low? How is the centre of gravity in plants and animals situated?

38. Name another kind of attraction besides that of gravitation. Under what circumstances does it act? What does it cause? What makes a solid body?—a liquid?—a gas?

39. What effect does cohesion produce on a small detached portion of a liquid? What other force has the same effect? What does this law lead us to infer?

40. Do only particles of the same kind stick together? Give instances of particles of different kinds adhering. What curious effect does this property give rise to?

41. Is it more natural for a body to be at rest or in motion? What, then, *is* natural for a body in this respect? Is it in a curve or in a straight line that a body continues to move when let alone? If kept moving for a time in a circle, would it not go on in a circle when left to itself? What hinders a cricket ball from continuing in motion? When does it stop? What makes us think at first that rest is more natural than motion?

42. What is the tendency of the outer parts of a revolving body? What hinders them from obeying it? Give an instance of a body obeying the tendency. What name is given to

the force that impels a revolving body to fly off? What would the inward pull of the string of a sling be called?

43. In what direction has a planet at every instant a tendency to proceed? What hinders it? What is the result? What two things must be suited to each other? If the earth were nearer the sun than it is, would it require to move faster or slower?

44. What is supposed by some to have been the original state of the sun and planets? How were the planets formed? What does the simplicity of the laws of motion of the planets shew?

45 and 46. If the earth is wheeling round, why do we not see the motion, and feel ourselves carried through the air? Why does a stone, when dropt from a height, not fall to the westward of the spot immediately under it? What makes a man fall when he leaps from a rapidly moving carriage?

47. How may a man lift a weight that he could not move with his hands? What is such an instrument called? How ought a lever to be held to get the greatest advantage? What *dis*advantage arises from this? What do implements really enable a man to do? Instance another machine besides the lever. Does a block of stone in a crane move as fast as the handle?

48. What has man done besides turning his own strength to better account? What is his most powerful auxiliary? What effect has the extensive use of machinery had on the necessaries and comforts of all classes of the people?

49. What is the science of the moving of solid bodies called? Explain Attraction, Gravitation.

50. What is the earth chiefly composed of? What general name is given to the substances composing the earth?

51. In what two forms are all rocks found? Give the names.

52. Is there any order observable in the disposition of the rocks? Does it strike a person looking at them without care and reflection? Is it long since the order was noticed?

53. Give examples of what is meant by the fixed order of the rocks. Illustrate it by the letters of the alphabet. Where are the oldest rocks?

54. What lies under the stratified rocks? Are unstratified rocks always on a lower level than the stratified? In a mountain how are the two kinds often disposed? Where else do we find unstratified rock?

55. What produced the unstratified rocks? What name do they get from this? What is a volcanic rock? How were the stratified rocks formed? What called?

56. Describe the appearance of the unstratified rocks. Of what four substances are they composed? Are these substances always in the same proportions? What is the most common kind of unstratified rock? Describe it. What is it used for?

57. Describe the lowest group of stratified rocks. What one is like granite? What peculiar structure have other members of this group? Name the group.

58. What happens to all rocks when exposed? Where are the worn-down particles carried? Describe how the stratified rock would be formed from the unstratified.

59. What name is given to the wearing down of rocks? What would have happened if there had been nothing but disintegration going on? What hinders this? How does the elevating principle act? Give instances where its operation has been seen. How can we infer in many cases that the land must have been raised up? Is raised land permanent?

60. When loose matter is suspended in water, what parts will be first deposited? In clay-slate, what must have happened to the materials? How do the crystals of gneiss differ from those of granite?

61. What rocks come next? and above that? Describe and name the next series of strata. What succeeds the Silurian system? Are all rocks of the old red sandstone system red in colour? Describe conglomerate. Give another name.

62. Where do remains of plants and animals begin to be found? When must they have lived? Are the flesh and bones of animals, and the wood of trees, still preserved? How, then, are they known to be remains of such? What are they called?

63. What are found in the greywacke? What of the Silurian strata as compared with the greywacke? Name a few species of fossils. What are found in the old red sandstone? Had the fishes scales?

64. What formation comes next? Describe it, and the fossils found in it. Why is it called carboniferous?

65. What does the coal lie above? and what strata accompany it? How were coal-beds formed? Describe the plants found in the coal, and what inference is drawn from them.

66. Above the coal comes what? What is sandstone composed of, and what is it good for? Where is the best building sandstone found?

67. What is the next group called? What is found among these strata? What is limestone composed of? Whence came the lime of those beds? What is marl? Describe kinds of marl. What is gypsum? What is plaster of Paris?

68. Where does shell limestone come in? What is it

remarkable for? Name and describe two monstrous animals found in this group. What kind of abode may we infer they lived in?

69. After shell limestone, what comes? What is the lias group? What does it contain? What substance is got from one bed?

70. What is the oolite group composed of? Why so called?

71. The next group? Explain the name. What stone is found in the chalk? What use is made of it?

72. Are all these rocks to be found in the same place? What is the highest formation in Scotland? What of England in this respect? Do the rocks ever occur in any other order than now described? Is coal ever found under old red sandstone? Is the knowledge of this order of any practical use?

73. How are we able to get at the lower rocks? What is a *hitch* or *fault?* What is a *dike?* What inconvenience do they cause? Do they ever do any good?

74. What is the cause of the upheaving of rocks? In what positions is the melted matter found? What general term is applied to unstratified rock of this kind? Name the varieties. What shapes do rocks of this kind often present? In what places are these appearances to be seen? What proofs of wisdom and goodness are to be seen in these arrangements?

75. Explain what rocks were meant by *primary*, *secondary*, and *transition* rocks. How are rocks now divided?

76. Explain the circumstances in which the tertiary formation, or cainozoic, came into existence.

77. What are found in the lowest beds of the tertiary formation? Where are the first remains of land quadrupeds found? What order are they of? Do the same species now exist? Name and describe an animal often found. How are the remains of fresh-water animals and of marine animals disposed? Describe how the remains of existing kinds of shell-fish increase from below upwards. What happens with regard to land animals as we ascend? What do we infer?

78. Could all these rocks have been deposited in a short time? Were human beings yet upon the earth? or even many of the quadrupeds and birds?

79. What must have followed the formation of the tertiary rocks? What is at the bottom of these accumulations? Why is it called *drift?* What appears to have been the agent in causing it? What often lies above the drift? How were these beds formed? What is alluvium? What are places formed of alluvium called?

80. What formations are still in process of growth? What is vegetable soil? What does the nature of the soil depend upon?

81. Can we expect actually to see an uninterrupted series of the rocks, the one lying above the other, as in the figure, p. 34? Explain how the tertiary strata in p. 35 can be said to be above the coal-beds, when they are actually on a lower level. Point out the *fault* in the coal-beds.

82. What do the rents in the primary and secondary rocks often contain? What are the most useful metallic ores got in these veins? Name some of the stones called precious. Of the common minerals, which are the most generally useful?

83. What is geology? What is the derivation of the word? What is mineralogy?—mining?—metallurgy? What is the science or art of turning vegetable soil to account called? Explain what is meant by 'the crust of the earth?' Are we sure that the earth is solid to any great depth? How does Syenite differ from common granite? Whence comes the name? What is the appearance of mica and talc? What does the fossil Ammonite get its name from? Why is trilobite so called? Explain Ichthyosaurus, Plesiosaurus, Palæotherium, Delta, Oolite, Silicious, Calcareous.

84. What is the difference between the two diameters of the earth? What is the *crust* of the earth? What do the hollows form? State the extent of the surface. What proportion is water? Define an *ocean*, and a *continent*.

85. Why is the map of the world in two halves? What does the eastern hemisphere contain? What is the western continent called, and why?

86. What separates America from Europe? Does the Atlantic separate anything else than Europe from America? Where lies the Pacific?—the Indian Ocean? What other oceans are there? Define an island. What is the largest island? Name other islands. What is a peninsula?—an isthmus?—a cape?

87. What is a sea?—a bay?—a gulf?—a strait?

88. What names are applied to extensive plains? Name the most extensive tract of mountains. What are parts of it called? Name a tract in the New World. Where are the Alps?—the Pyrenees?—the Uralian Mountains?—the Dofrafields?—the Cheviots?—the Grampians? Where is the highest peak?

89. What do some mountains throw out? What are they called? Name a few. Where are the greatest number of volcanoes? How got they their name?

90. What is the torrid zone? Name the other regions

of the earth. Illustrate the climates of these regions by an example. When the sun's rays are midway between horizontal and perpendicular, what happens? What else affects temperature? How high is the snow-line at the equator?—in Britain? What height makes the thermometer fall a degree? What effect has the neighbourhood of a sea? What is the result of these modifying circumstances?

91. With what is the earth clothed? What things are necessary to the growth of plants? Whence do they get heat?—and moisture? What does rain furnish, besides moisture, to plants? Of what use are rivers?

92. Are plants everywhere the same? Would the whole of the plants of our climate grow in the torrid zone?—or at the poles? How may the plants of all regions be seen in the same country?

93. Does the temperature of the sea vary as much as that of the land? What motions has the water of the sea? How does it resemble the land? What is a *terrestrial* animal? What is contrasted with *terrestrial*? What is the difference between *marine* and *aquatic*? To what parts of the sea are plants and animals confined?

94. What are the subjects of physical geography? Explain Peninsula, Geography, Physical.

95. What two meanings has the word *heat*? Which has it in science?

96. Is its nature known? What two opinions have been held? Which is considered the more probable?

97. To what does the heat of all neighbouring bodies tend? What happens when a stone is taken into the hand? Why does the stone feel cold? How may the same water be made to feel cold to the one hand and warm to the other? Is cold anything positive? Is there any body absolutely without heat?

98. Do all bodies convey heat equally? Illustrate this inequality. Why is the handle of a silver teapot made of wood? What is silver called as compared with clay or wood? Is there any heat in woollen clothes? How do they act? When heat travels through the substance of a solid body, by passing from one particle to another, how is its passage spoken of? How is heat diffused through a liquid? Must one body touch another, in order to receive of its heat? How is the passage of heat without contact described?

99. What happens when ice is melted? What is insensible heat called? What happens when water turns to ice?

100. What are the chief sources of heat? How else may heat be produced? What often happens to the axles of

wheels? How may fire be got out of air? What cold substances will produce heat by being mixed? Give instances of *spontaneous combustion.*

101. What general effect has heat on bodies? Express this as a law. Give instances. How much is water expanded when it becomes steam? What use is made of this?

102 and 103. What kind of bodies radiate heat best? and what kind absorb it best? Which are the worst radiators and absorbers? Illustrate this.

104. Why does polished metal not become readily heated by the rays of a fire? How may the sun's rays be made to melt metal?

105. What would happen if heat were withdrawn from matter? What is *temperature?* How is it measured? Describe the thermometer. At what degree is the freezing-point? How many degrees is *zero* below this? What is *temperate?*—blood-heat? At what degree does water boil? Explain the words Radiation, Reflect, Repulsion, Thermometer.

106. What is freezing? When does ice begin to melt? What happens to water in freezing? What does this occasion? Why does ice float? What are large masses of ice called? Where besides do large masses of ice form? What is an avalanche?

107 and 108. What is snow?—hail?—sleet?—hoar-frost? Of what use is snow?

109. At what temperature does olive-oil freeze?—milk?—quicksilver? Mention an easily prepared *freezing* mixture. What degree of cold does it produce? Explain the words Glacier, Avalanche.

110. Is it known with certainty what light is? State two opinions about it, and which is now generally held. What, then, do we know about it?

111. State one fact about its progress. How was this discovered?

112. In what form does light travel? Can it go through any substances? What are they called?—and other bodies? What is meant by light being reflected? At what angle is light thrown back from a mirror?

113. Does a ray proceed straight through such a body as air? What happens when it passes from air into water, or glass? What is this called? What common appearance does refraction explain? On what does the refracting power of a medium depend?

114. How may a white ray be divided into coloured rays? Name the colours. What do they form? Where do we see these colours in nature? How is the separation caused?

Which ray is *least* refrangible? How is green light formed? —and white?

115. What effect has light besides letting us see? What does it do to vegetables? Does it affect animals? Mention some effects on dead matter. What two arts depend on this property?

116. Does vision take place by anything proceeding from the eye, or from the object seen? What is the science of light called? Explain Luminous, Transparent, Opaque, Refraction, Photograph.

117. What was the first electrical appearance that was observed? Whence came the name? What besides attraction was next seen? Do we know whether electricity is actually a fluid? What else may it be? Why do we speak of it as a fluid?

118. Is electricity confined to certain bodies? When does it become sensible? What happens when glass is rubbed? What tendency has an electrified body? What is seen as electricity is passing from one body to another?

119. What is meant by being *positively* electrified?—*negatively*? How else is this matter viewed? When an excited glass-rod is brought near a pith-ball suspended by a silk thread, what happens at first?—the second time? What happens with a wax rod? What happens when the wax rod is presented after the glass, or the glass after the wax? State the four facts or laws separately.

120. What two names are applied to the electricity arising from glass?

121. What is an electric machine? In what is the electricity collected? What is the feeling when it is made to pass through the body? How may an ox be killed by it? What is an electrical battery?

122. What is a *conductor* of electricity? Name some of the best conductors and non-conductors. What turns a non-conductor into a conductor? Why should a living tree be a good conductor, when dry wood is a bad conductor? What is the meaning of *insulated*? What class of bodies form insulators?

123. How does the air become charged with electricity? How does it shew itself? What do ignorant nations think of thunder?

124. What mischief does lightning often do? How may this be guarded against? What use has been made of the rapidity of electricity? Give another instance of its use.

125. Do thunder-storms extend as widely as other storms? When the thunder is long in being heard after the flash, what may we infer, and why? How fast does sound travel? If the interval is four seconds, how far off is the discharge?

126. What bright appearance besides lightning is attributed to electricity?

127. What connection with animals is electricity supposed to have? Is any animal remarkable in this way? How does this power serve the animal?

128. What other phenomenon is electricity thought to be the same as? How does magnetism shew itself? What natural product has it? What are the opposite parts of a magnet called? What may the earth be considered as? What useful instrument has this given rise to?

129. Name various ways of exciting electricity. What uses have electricity and magnetism been turned to? Explain Vitreous, Resinous, Equilibrium, Telegraph, Loadstone.

130. With what is the earth surrounded? How do we become aware of its existence? How high is the atmosphere? What makes it denser below than above?

131. What is it composed of? Which gas is in greatest quantity? Would other proportions do as well? Which is the vitalising ingredient? How does it act on animals? What results from long breathing in a confined place? What should we be very careful therefore to do? Why does not the whole atmosphere become, in time, unhealthy?

132. What effect would the want of an atmosphere have on sound? Why? Can air be weighed? How much is the weight of the whole atmosphere on a square inch of surface? What does this amount to on the surface of a man's body? Is the pressure all downwards? Is it oppressive? What would happen if it were removed?

133. Give instances of the effects of this pressure. Explain the way that the pressure of the air lifts up the stone under a leather sucker.

134. What substances rise up through water? What substances, then, will rise up through air? How high will they rise? What is a balloon? What limit is there to the weight that a balloon will raise?

135. What height of a column of water is of the same weight as an equal column of air the whole height of the atmosphere? What makes water rise in a pump? How high will it rise? What height of mercury is equal in weight to the atmosphere? Is the atmosphere always of exactly the same weight? How may we measure its changes? When it is lighter than usual, what generally follows? What may we infer, then, from the height of the barometer?

136. Explain how the pressure of the atmosphere affects the boiling of water. Can we breathe as well on a very high mountain as at the foot of it? Explain Barometer.

137. What is wind? What is the most frequent cause of winds? What happens when the door of a warm room is opened? How are the trade-winds caused? What are some of the uses of winds?

138. Mention some particular local winds.

139. What is always going on where water or moisture is exposed to the air? Is true vapour visible? What, then, is the smoke coming from anything wet held to the fire? What is the term for turning vapour back to water?

140. What does the amount of evaporation depend upon? If the air above water were prevented from changing, would evaporation go on without limit? When it stops, what is the air said to be? How could the same portion of air be made to hold more vapour? But suppose a portion of saturated air to be cooled down a good many degrees, what takes place? Is the air necessary for this process of evaporation and condensation?

141. What does all this explain the formation of? Describe the process. How may strata of the atmosphere be cooled? When air ascends into the higher regions, what two things must always happen to it? How do mountains cause clouds?

142. What holds up the water-dust that forms clouds? Do we know what makes rain begin to fall from a cloud? How are the drops formed? How may a cloud disappear without rain? In what kind of weather is dew most likely to form? Do we see it falling? Explain it. Why do the drops adhere chiefly to hairs?

143. State the two uses of clouds.

144. How is artificial evaporation caused? What is the rapid evaporation produced by fire called? What is vapour at boiling heat called?—its use?

145. What are the subjects of meteorology? Explain the word. How many sorts of meteors are there?

146. What, next to air, is perhaps the most generally diffused and useful substance? What is water composed of? and in what proportions? What arises from the slight cohesion among its particles? How does the pressure of liquids differ from that of solids? What is one consequence of this? What does a knowledge of the fact that a body of water rises in all parts to the same surface-level enable us to do?

147. What phenomena does the property of *flowing* give rise to? Is any use made of the force of water?

148. What objects float on water? Is the weight of a body that is heavier than water at all affected by being immersed in it? How much lighter is a cubic foot of iron in water than in air?

149. Name three sciences that treat of water, and explain the names.

150. What are all bodies ultimately composed of? Are we quite sure that these are all distinct simple substances? Do we often see the elements by themselves? In what state do they generally exist? What does this constitution of things shew?

151. What is the subject of chemistry? Is it an old science?

152. Name the elements that exist as gases. Which are the most important?

153. How many metals are there? Which are best known? Name some of the rare metals that are of little importance.

154. Under what disguise were twelve of the metals discovered? How were the new metals named? Mention some of the metals of the earths, and of the three alkalies.

155. What are the remaining elements?

156. Which elements have the greatest power of combining with other elements? Which one most of all?

157. What is the most common preparatory combination of elements? Give examples of an oxide. What is a compound of chlorine with another element called?

158. What element unites with a metal to form an earth? Are the metals of the earths ever found in nature by themselves? What are the names of the earths?—their characters? Which are the alkaline earths? Which are very abundant? What, besides lime, is there in limestone?

159. What are potash and soda compounded of? What is the other alkali formed from a metal? What is ammonia? Where do potash and soda abound? What are their uses? What is the nature of ammonia? What are the distinctive properties of the alkalies?

160. What is remarkable about potassium and sodium?

161. What general name is given to oxides, earths, and alkalies?

162. What distinguishes acids? What change in colour do they produce? What is the result of mixing an acid with an alkali? What is generally an ingredient in an acid? What was one time thought regarding oxygen? Name an acid that has no oxygen. What is the new view regarding acids? Does oxygen ever form both a base and an acid with the same element? How do the two differ? Does oxygen ever form more than one acid with the same element? How are the two distinguished? Give examples. How are the salts formed by the acids distinguished? Name some of the most important acids. What distinguishes the vegetable acids?

163. What do salts arise from? Where are they found

abundantly? Are all the ingredients of both acid and base found always in the salt? What is the best known of all salts? What is it composed of? What acid and what alkali if brought together form common salt? How are they composed? What becomes of their other elements?

164. Are chemical combinations like mixtures? What is the leading law of combination? Illustrate this in the case of water. How are oxygen and hydrogen made to combine? In what proportion must they be mixed if we wish the whole of both gases to be taken up? Mix five grains of hydrogen with twenty-four of oxygen, and what will remain after union?

165. Do oxygen and hydrogen form any other compound than water? What is the proportion of each in this case? How is this proportion as compared with that in water? State this law generally.

166. What theory about the constitution of matter has been formed to account for the fixed proportions in which elements combine? What is the meaning of *atom?* What is supposed about the atoms of different elementary substances? Describe the combination of oxygen and hydrogen on this supposition. Is there a greater number of atoms of oxygen in water than of hydrogen? Why, then, is there a greater weight of the one than of the other? What takes place when deutoxide of hydrogen is being formed?

167. In a compound substance, are the properties of the elements that compose it generally discernible? What is often the case when the same elements unite in different proportions to form different substances? What changes often come over gases when they go into composition? What does this easily account for?

168. What are two chief agents in making old combinations break up and new ones form? Do bodies act on one another readily when dry? What effect has water on a great many bodies? Is the division minute? How does heat act? What use does the chemist make of evaporation? When water is evaporated from a solution, in what form does the substance often appear? Give instances of crystallisation. How may crystals of lead be formed?

169. What is the fundamental cause of all chemical phenomena? What is the kind of attraction that operates among the atoms of bodies in contact called? Is the force of affinity the same between all atoms? What effect must arise from this difference? Give an example. Could you give an example of a series of dislodgments? What happens when a number of compound substances are brought together?

170. Has chemistry anything to do with the growth of

plants? What connection has it with the growth and health of animals? Mention arts that depend on chemistry. Explain the words Oxygen, Hydrogen, Atom, Chemistry, Affinity.

171. What is meant by *organic* bodies? What do they require while alive? What bodies are contrasted with organic ones? Do all the elements enter into organic bodies?

172. What two departments are there in the organic world? What properties of animals do plants want? What grand purpose do they serve? They are thus a step from what to what?

173. What do plants require for their growth? How many kinds are known to exist? What classes of plants do people readily form, without special study?

174. How are plants reproduced? On what is the classification of Linnæus founded? What are the two chief parts in the reproducing organs? How do plants differ with respect to these two parts? How many classes did Linnæus form out of these varieties? Name a few of them, explaining the meaning of the names. How did he further divide his classes? What other classification is there? On what principle is it founded? What is the first division in this system? Name four families, and explain the names, giving examples.

175. What is the part called that contains the seeds? What makes the seeds fertile? Describe the arrangement by which the pollen is made to fall on the pistil. How is this effected, when the stamens and pistils are far asunder? What is required to make a seed spring? What is the first step in this?—the second? What does the body of the seed do? What purposes does the root of a plant serve? Name a seed that springs quickly.

176. Name the chief parts of a plant. What does the *filament* support? What are the two portions of a flower? How does a shrub differ from a tree? How does the stem of a tree differ from that of a thistle?

177. Whence do plants draw their food? What does it chiefly consist of? Where does the ascending sap go to? What takes place in the leaves? Is it only by their roots that plants feed? What do they get from the air? How are these substances supplied to the air? Where does the sap go from the leaves? Where is the new matter deposited? What causes the rings to be seen in wood cut across? Do all plants increase on the outside? What is true about the seeds of the two kinds of plants? What happens in winter?

178. What effect has the want of light on plants? What gives plants their green colour? Why is it hurtful to sleep in a room where there are many plants?

179. How may useful vegetables be classed?

180. Name the chief grains. What name do they get in science? Which is chiefly raised in England? Do grains grow wild? What part of a grain-plant is the useful part? Is any use made of corn besides bread? What are pease and beans called?

181. Is pasture made up entirely of grasses? What is an *artificial* grass? Is clover a grass, strictly speaking? Is anything used as fodder besides grass?

182. Name the chief *esculents*. What country is the potato a native of? When did it first come to this country? When did it become common? What esculents were much earlier known? Name other plants of the same family. Are the wild plants of this kind useful?

183. Where is tobacco cultivated to a great extent? What part of the plant is used? Is it essential, or even useful? Name a very useful shrub, and in what countries it is cultivated. How much cotton is raised in the United States in one year? What is linen got from? Describe the sugar-cane, and how it is planted. How is sugar extracted from it?

184. Name a few herbs that are used as food—as medicine—as seasoning.

185. Which are the most important fruit-trees? Do they all grow in this country? What is the fruit of the vine called? Where is it chiefly grown? Which are the most abundant fruits in this country? What other country produces apples in abundance?

186. What is cinnamon? Where does coffee grow? and tea? When were coffee and tea introduced into Europe? How much tea is annually used in Great Britain?

187. Name the most common timber-trees. What tree lives very long? What is it much used for? Why do we not grow all the timber we need? Where does mahogany come from?

188. What does the science of botany treat of?

189. Do animals inhabit every part of the earth? What portions of the earth are uninhabited by animals? In what points do animals differ from plants? Is *man* an animal? What rank does he occupy in the animal creation?

190. What kinds of animals has every one observed? Are there animals we do not see? How are the wisdom and goodness of God seen in regard to the animal world?

191. What chiefly distinguishes the humbler from the higher kinds of animals? What kinds of animals are produced in great abundance? Do all animals possess an equal share of intelligence?

192. How did Cuvier arrange the animal kingdom? What provinces or sub-kingdoms did he make? and explain the Latin names. What is his arrangement based on? What subdivisions did he make? What form of animal life is *species* applied to?

193. What is the lowest province of the animal kingdom? What kind of animals does it include? How many classes does it comprehend? Name them.

194. What is the first or lowest class of the province Radiata? What class do animalcules belong to? From what does the class take its name? Mention one *order* of this class. What do we know about the animals composing that order? Mention another order. How do they propagate their species?

195. What is the second class of the province Radiata? From what does this class get its name? Name one of the orders. What is peculiar about the *hydra*, and where does it live?

196. Name any other orders, and mention any animals that belong to them. How is coral made? Where does it chiefly exist? How many varieties of coral are there? Where is sponge found? What kind of substance is it?

197. What is the third class of the province Radiata? What kind of creatures does it include? What peculiar power does one of the animals in this class possess?

198. What is the fourth class of the province Radiata? Mention any of the animals composing the class.

What is the last class of the province Radiata? Give two examples.

199. What is the second province of the animal kingdom? What is peculiar to the animals composing it? Do they live in land or water? How many classes are they divided into? Name them.

200. Name the most important class, and give the reason. Mention one order.

201. Name the second order. Where do the animals of this order live? Name the third order, and repeat the names of a few of the animals belonging to it.

202. What is the second class of the province Mollusca? What kind of animals compose the class? Into how many orders has Cuvier arranged the class? What plan did he take in arranging them? Name a few examples. What is meant by Pteropoda? What animal does the whale chiefly feed on?

203. Name the third class of the province Mollusca. Why is it so called? Where do the animals of this class live? Name two animals of the class. What is remarkable about the cuttle-fish?

204. Name the third province of the animal kingdom. What are the chief characteristics of the animals composing it? How many classes did Agassiz divide it into? Name them.

205. What is the first class of the province Articulata? What kind of animals does it include? Why are they called *Annellata?* Give a few examples.

206. Name the second class of the province Articulata. How many orders is it divided into? Mention any one of these orders, with a familiar example. Name another, &c. To what kinds of animals has the term *Malacostrata* been applied? To what, *Branchiopoda?*

207. To what order does the barnacle belong? Where does the barnacle live?

208. What is the third class of the province Articulata? How many orders does it comprise? Name the first order, with example. The second, &c. What order does the dragon-fly belong to? The cockchafer? The house-fly?

209. Which of the Articulata are the most remarkable for intelligence? What part of the habitable globe are they found in? How many legs have they? Have they a brain? What senses do they possess? Is there anything peculiar about the eye of an insect?

210. What do insects live on? How do they propagate their species?

211. Explain how the butterfly comes into life. Why has man always regarded insect transformations with peculiar interest? Can the rudiments of the perfect butterfly be traced in its earlier stages?

212. What are the most beautiful kinds of insects? Are there many kinds of butterflies? Where are the largest found? What is peculiar in the wings of butterflies as regards their colour? How many lenses have been counted in the eye of a butterfly?

213. Explain the meaning of the word *cocoon*. Give an example.

214. What kinds of insects live in a state of society after the fashion of the human race? How many bees are there generally in a hive? Are they all of one kind? What is the principal female in the hive called? Why?

215. How do bees suck up honey? In what way do they carry it home? Of what substance are honey-cells composed? Do bees carry home any other substance besides honey? How do they carry it home? Why do bees store honey? What becomes of the male bees at last?

216. Do ants shew as much ingenuity as bees in the

construction of their dwellings? Where are ants chiefly found? Why has the ant become proverbial for her industry?

217. How many orders are the *Arachnida* divided into? Name them, with examples.

218. Where does the thread come from of which the spider makes her net? Can the spider repair her net when it is broken? What do you know about the scorpion?

219. What is the fourth province in the animal kingdom? What distinguishes the animals of this province from those of the other provinces? How many classes is the province divided into, and name them? Where do the animals of the first class live, and how do they breathe? Whether is the blood of fishes and reptiles warm or cold? What distinguishes the heart of cold-blooded from that of warm-blooded animals?

220. How many orders is the class Fishes divided into? Name the first, with examples; the second, &c.

221. Is there anything peculiar in the breathing of reptiles? Do all reptiles possess limbs? How many orders are there in the class Reptilia? How are the bodies of tortoises protected? Mention something remarkable about tortoises.

222. What is the second order of the class *Pisces* or Fishes, and give one or two examples. What kind of an animal is the dragon? Do you know anything strange about the chameleon?

223. Name the third order, with examples. How do the animals of this order move? Mention something remarkable about serpents.

224. What is the fourth order? and give one or two examples. What are the animals of this order chiefly remarkable for? What are young frogs called? Do the animals of this order always live in the water? What are they sometimes called, in consequence?

225. What is the third class of the Vertebrata? What are the distinguishing points about the animals of this class? How many orders is it divided into?

226. What is peculiar about the heads and feet of the order Natatores? Do swimming-birds always remain in this country?

227. Mention a few of the birds that rank under the order Grallatores. Where do they chiefly catch their prey?

228. What is the meaning of the word *Cursores?* What species of birds does it include? Are any kinds of the Cursores found in Europe?

229. Name another order, and give a few examples. To what order do *game*-birds belong?

230. What are the distinguishing points in the *Raptores?* Name a few of them.

231. To what order do perching-birds belong? Give a few examples. What do you know about the humming-bird?

232. What is the distinguishing mark of climbing-birds?

233. Name the last and greatest class of the province Vertebrata. What distinguishes the Mammalia from all other animals, and why may they be said to stand at the head of the animal kingdom?

234. What is peculiar to the animals called Marsupialia? Name a few examples. Are they all of similar habits? What is remarkable about the ornithorhynchus?

236. What is the meaning of the word Edentata? What animals does this order include? What are the names of the two animals of this order whose remains have been found in rocks?

237.. What order do hedgehogs, moles, and shrews belong to? Can the mole see or hear?

238. What name is applied to gnawing animals? Mention a few examples. Mention any peculiar points you know about the animals of this order. What animals excel all others in the construction of a dwelling? How are their dwellings made?

239. Do any of the Mammalia live in the sea? How many families of the Mammalia live in the sea?

240. What is the name of the family to which whales belong? What is the most remarkable species of whale? What is its length? Why are whales sought after? What is whalebone? How does the whale progress through the water? Can the whale be properly called a fish?

241. What is the name of the second family of the Swimming Mammalia? What animals rank under this family? Mention an animal that belongs to the third family. What is remarkable about the narwhal?

242. What kinds of animals does the order Ruminantia comprise? What do the animals of this order live on? Why are they called Ruminantia? Describe the process of 'chewing the cud.' What is the term Ungulata applied to? What substances do the Ruminating animals furnish for the use of man?

243. To what order do thick-skinned animals belong? What is the largest land animal? What is the use of the elephant's trunk? What familiar animals belong to this order? What distinguishes the horse, zebra, and ass from the Ungulata?

244. To what order do beasts of prey belong? Mention a few examples. What is the meaning of Plantigrada? What name is applied to those animals that walk on the ends of their

toes? Name a few of the animals. What are the distinguishing points of the lion, tiger, &c.? What is the lion called? Why?

245. What animals belong to the order Cheiroptera? What is remarkable about them? What do you know about the vampire-bat?

246. To what order do monkeys belong? What are they remarkable for? Where do monkeys live in a wild state? What is the most remarkable species? What kind of monkey is considered the most intelligent?

247. What creature ranks as the highest order of the class Mammalia? What is the name usually applied to the order?

248. What science treats of animals, their varieties, habits, and modes of life? What departments is the science divided into? Name one or two of these departments.

249. What two things distinguish man from all other animated beings? Is man exactly the same everywhere? Where do the white-skinned varieties inhabit? What have they been called? Where is the home of the Mongolian race? What are their distinguishing characteristics? Name and describe the race that inhabits Africa. What is the colour of the natives of America?

250. Which variety is the most improvable?

251. In what countries did civilisation first advance? What people do we get the history of in the Bible? When did their progenitor live? What ancient nation excelled in art and literature? What were the Romans remarkable for? When, and how long did the civilisation of the Greeks and Romans flourish? When do we consider antiquity as ending? What succeeded it? What recovered society out of its barbarism? Which nations became the most civilised? Where besides has civilisation spread to?

252. What has happened in some of the early civilised countries?

253. What are the sciences that relate directly to man? What does philology treat of? History? &c.

254. Which of the sciences that treat of man is it most needful for every one to know? Why?

255. When does man attain his full growth? At what period of his existence is he in the prime of strength? Elderliness? Old age?

256. What name is given to the human framework of bones? What is the principal part of the skeleton? Name another portion of the skeleton and its position. Another, &c. How many bones is the human skeleton composed of? What is bone made of?

258. What does a great portion of the soft substance of the body consist of? How may the substance termed muscle be described? Where are the chief muscles placed? When we desire to move a limb, by what controlling power are the muscles made to act? Are any of the muscles exempt from the will? What are they termed?

259. In what parts of the body do the nerves exist? What parts do they communicate with? What is the nervous system, and why is it so called? Describe the appearance of the nerves.

260. Describe the appearance of the brain, and where is it situated? Why is the brain so well protected? Describe the construction of the skull. What is the cerebellum? Is the brain confined solely to the head?

261. Which of the nerves originate in the brain? Which from the spinal cord? Which in the breast?

262. How is perception of the external world communicated to the organ of thought? How many senses are there?

263. Which is the first sense? Describe the construction of the eye, and how objects, through it, are communicated to the brain.

264. Which is the second sense? Describe the tympanum. What is sound, and how is it conveyed to the brain?

265. Which is the third sense? Where does the sense of taste reside?

266. Which is the fourth sense, and where is it situated?

267. Which is the fifth sense, and where does it chiefly reside?

268. In what part of the body are the organs placed that propel blood through the system? What is that part within the cavity of the ribs called? What divides it from the lower part of the body? What divides the right side of the chest from the left? What does the left cavity of the chest contain? What the right? Describe the construction of the heart. What is the use of the heart? What are auricles and ventricles, and where are they situated? When the left ventricle contracts, what takes place? Whether do the arteries convey blood to or from the heart? What function do the veins perform? What appellation is given to blood that has passed through every portion of the body? Upon leaving the right ventricle, where does the blood go? When does the blood pass into the left ventricle? What is the passage of the blood through the lungs called? What are the emissions of blood from the heart called? What weight of blood has a full-grown person?

269. Of what use are the lungs? Describe their appearance.

What becomes of air after it is inhaled by the mouth? Why do the ends of the air-tubes mix intimately with those of the blood-vessels?

270. Where are the alimentary organs situated, and of what do they consist? What first becomes of food after it is swallowed? Describe the process of digestion. Trace the progress of food after it has been converted into chyme. After it has been further converted into chyle. What becomes of the remainder of the food not acted upon by the gastric juice. Describe the appearance of the intestines. Name one of the six portions into which they are divided. Another, &c.

271. What functions does the blood perform after it has received the essence of the food, as above described? Name the principal secreting organs. What is remarkable about the liver? What is the pancreas like, and where is it situated? What purpose does it serve? What are those glands called which are placed in and around the mouth? What is their use? What glands are placed in the inner corner of the eye-socket? What is their use? Mention any other secreting glands.

272. Which are the principal excretory organs? What purpose do the kidneys and skin serve?

273. Upon what does health mainly depend? From what causes does disease arise? When death occurs before old age, to what cause is it attributable?

274. What will do much to preserve health, and prolong life under ordinary circumstances?

275. What kind of knowledge is serviceable for preventing injuries to the structure of our bodies? Specify what we ought to know and study.

276. What things are, above all others, required for keeping the organic structure of the body in a healthy performance of its functions?

277. When is air in a proper state for the support of the organic functions? Why should sitting and sleeping apartments be large and high in the ceiling, or have constant communication with the air? Where is the air most wholesome?

278. Name some articles of food not easily digested. What liquors are hurtful to the digestive powers, if taken in large quantities? Why should we be judicious in the selection and amount of our food?

279. What measures must we take besides those of supplying the blood with what it requires for the support of the system?

280. What is necessary for this? What is the direct object

of supply? In what state of mind and body does this supply and waste become too languid? How are the muscles acted upon by the blood through exercise? What is the result of moderate exercise to our bodily frames and health? What is the result of indolence?

281. What is the fourth requisite for health? What are necessary for preserving the skin in a healthy state? At what time of life ought habits of cleanliness to be formed?

282. What relation do the mind and brain bear to each other?

283. In what way do you feel that the mind acts with regard to various things and actions presented to your notice?

284. Into what classes would you divide the faculties of the mind?

286. What are the knowing faculties? and mention one or two of them.

287. What are the other class of intellectual powers called? Name one, and describe it. What kind of persons chiefly exercise this power?

288. Which is the second of the reflecting faculties? In what way does reason elevate man above all other animals?

289. What are the affective faculties?

290. What stands first among the moral sentiments? How does veneration cause us to act? What sentiment comes next? What does it prompt us to do? Which comes next? What is justice otherwise called? How does it affect us? Of what does practical Christianity consist?

291. Are there any other orders of sentiments besides those just named? Name one sentiment, and what it enables us to do. Another, &c.

292. What three sentiments does the third order comprehend?

293. Name one of the sentiments embraced by the last and lowest order. Another, &c.

294. What is the simplest operation of the knowing and reflecting faculties? What does attention qualify us for? Which is the next operation? Why has perception been given to us? What is memory? In what way do the faculties act to produce conception? Imagination? What is association? To what is dreaming attributable?

295. What do the knowing and reflecting faculties render us, when rightly directed? What do the moral sentiments give us? What does the second order of sentiments furnish us with? The third? What do these sentiments produce in excess? What propensities do the fourth order contain?

296. Can the sentiments act singly only? Give an

instance of a sentiment acting singly. In combination. Another. How must the lower sentiments be trained to act? Are our faculties, as a general rule, always active? How are many led to err with regard to the lower sentiments?

297. What is the first condition upon which happiness mainly depends? The second? The third? The fourth?

THE END.

Edinburgh:
Printed by W. and R. Chambers.

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